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TEMPORARY POSTURES IN SHELTERS:

A BEHAVIORAL PROBLEM AND SUGGESTED RESOLUTIONS

Prepared for:
DEFENSE CIVIL PREPAREDNESS AGENCY
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13. ABSTRACT

The purpose of this study is to identify the problems met in getting shelterees to take proper action for maximum protection utilizing the best protection areas in a building. Some areas offer greater protection than others and more lives could be saved in a disaster if people were to occupy the areas of best protection, even if this meant crowding for a brief period. Three buildings were selected to serve as examples to portray problems which might be met.

The report presents a model for placing people in the best areas of protection for periods up to six hours. The temporary postures recommended permits some flexibility to meet the needs of individuals and groups as they arise.

For conditions of overloading, the occupancy capacity of any given building is determined by the amount of space available with sufficient shielding for the extreme conditions of a burst's initial impact. The overload capacity of that shelter space is dependent upon the characteristics of its physical environment, primarily its ventilation capacity.

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Final Report
Detachable Summary

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DEVELOPMENTAL RESEARCH, INC.
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(Detachable Summary)

TEMPORARY POSTURES IN SHELTERS: A BEHAVIORAL PROBLEM AND SUGGESTED RESOLUTIONS

Disasters strain everyone and everything. Property is damaged or destroyed, people are injured or killed, and the threat, duration, and consequences of these produce psychological stress. The dimensions of disaster cannot be spelled out exactly--the variations are much too extensive--but certain conditions appear basic and form the basis for this study.

The purpose of the study is to identify and define the problems met in getting shelterees to take proper action for maximum protection utilizing the best protection areas in a building. Some areas offer greater protection than others and more lives could be saved in a disaster if people were to occupy the areas of best protection, even if this meant crowding for a brief period.

Three knowledge areas serve as a resource in the resolution of the problem set up for study. These areas are presented as the physical, the biological, and the psychological environments.

The physical environment in the study is a hostile one which could emerge during either a nuclear attack with high, medium, or low intensity blast effects or a natural disaster exemplified by a tornado or a flood. Three models are used as examples to demonstrate induced protective behavior from the hostile physical environments. These models include: a modern school building, a nine-story apartment building, and a high-rise office building. They were selected as being representative of buildings found in urban settings. The models include a variety of building construction to illustrate a variety of behavioral problems.

The biological environment is viewed in terms of the damage potential of the hostile physical environments. Basic life preserving action is necessary to prevent biological damage. Important damaging effects arise in a nuclear disaster from the blast and shock, the thermal radiation, and the nuclear radiation. In a natural disaster the biological damage arises from excessive water or winds, or their secondary effects. The kind and extent of biological damage depends upon the nature of the protection available.

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The psychological environment is the milieu in which behavior takes place. In it people respond as individuals and as members of groups as they attempt to deal with the conditions imposed by disasters. Disaster produces stress and this pervades behavior. Basic responses are made in terms of the time stage of the disaster with each individual following a predominant style of behavior. The individual is seen as having unique needs, resources, and experiences which occur as dimensions of his personality. A shelter population is seen to be made up of newly formed groups of such individuals. These interact within a newly formed structure to meet lifesaving goals which they hold in common with society as communicated through its civil defense.

Knowledge relating to the three environments has been summarized and used as the basis for setting up the problem and for its resolution. Identified in each problem resolution are the components of actions to be taken for maximum protection and steps necessary to communicate the directives to the people to obtain the necessary lifesaving actions.

Central to the resolution recommended is the provision for shelterees' psychological needs along with the necessary physical protection. The analysis found that total needs could best be met by allocating five square feet per person for short term occupancy in the best blast protection area, doubling the officially estimated shelter capacity. Groups of thirty-six people are to work together as a unit with, at any given time, one-third sitting on the floor and two-thirds standing, during periods of ten and twenty minutes, respectively. All take prone positions during the very short period when an attack is imminent and the direct effects of a blast are possible. At other times the sitting/standing sequence applies. The model is designed to cover a period of up to six hours duration, when an attack is expected. Following an attack, people would spread out into other areas for the longer period of confinement required for protection from fallout.

Behavioral problems are less likely to arise if the procedures set up for implementing the overloading conditions are used. The temporary postures recommendeded permit some flexibility to meet the needs of individuals and groups as they arise.

One building was not amenable to these conditions and served to demonstrate that the overcrowding capability of a building depends upon the characteristics of its physical environment, primarily its ventilation capability.

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ABSTRACT

More lives will be saved in a nuclear attack or a natural disaster if a maximum number of people occupy the areas of best protection. People should assume temporary postures in areas which are able to withstand the effects of the blast and thermal pulse of the burst. These effects produce the greatest physical damage and do so in a relatively short time.

If people assume temporary postures of sitting and standing and tolerate a degree of crowding for a brief period, approximately twice the number of people could receive maximum protection. The conditions of overloading would not last long and people would then spread out into other areas for the longer period of confinement required for protection from fallout.

For conditions of overloading, the occupancy capacity of any given building is determined by the amount of space available with sufficient shielding for the extreme conditions of a burst's initial impact. The overload capacity of that shelter space is dependent upon the characteristics of its physical environment, primarily its ventilation capability.

Behavioral problems are less likely to arise if the procedures set up for implementing the overloading conditions are used.

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TEMPORARY POSTURES IN SHELTERS: A BEHAVIORAL PROBLEM AND SUGGESTED RESOLUTIONS

I. INTRODUCTION

The goal of the study is to provide guidelines for maximizing the life saving potential of buildings as shelter in the event of a nuclear disaster, or thermonuclear detonation, and in such natural disasters as exemplified by floods and tornadoes.

Basic to the study is the belief that a shelter could handle more people than normal, if it must, but in order to do so people must be scheduled and placed according to the protection offered by the building in terms of the dangers present and within the psychological and physiological tolerances of the individuals. Thus, in times of intense danger, overcrowding might be scheduled to tolerance limits and then decreased as danger lessened; or, scheduling and placement might be a continuous operation, designed to handle continuing emergency conditions. When scheduling and placement have been determined, a second set of problems emerge which focus upon getting the people to implement the desired life saving actions. Thus, the problem set up for study is a two-fold one: determining actions to take and determining how to implement them.

The focus of the study is the problem defined, following guidelines discussed above, and solutions to illustrate the basic components of the problem. The solutions are in terms of representative kinds of buildings offering shelter under the conditions of nuclear and natural disasters.

The former emphasis upon protection from fallout has been augmented to include the effects of blast and thermal pulse, or thermal radiation, in addition to the hazards of fallout or nuclear radiation. The protection offered in the event of such natural disasters as floods and tornadoes completes the illustration of the solutions to the problem set up for study.

The report is organized into two major sections: a) the areas of knowledge basic to the solution of the problem and b) case studies to illustrate the solutions to the problem set up for study.

For the convenience of the reader, selections from the knowledge areas are included in the early part of the report. Three areas emerged as more relevant than others. They have been organized to include characteristics of: a) the physical environment produced by disasters, b) the biological

environment produced by the preceding hostile physical environment, and c) the psycnological environment encompassing disasters. The topic of communication has been included as part of the psychological environment. Discussion of these areas of knowledge appear in section II. For a more complete and definitive coverage, the reader is encouraged to refer to the primary sources of information as identified in the BIBLIOGRAPHY.

The problem set up for the study is defined and illustrated with solutions in section III. Three buildings serve as examples of physical protection and form the framework for bringing out the dynamics of behavior. They are: a) a modern three-story school building, b) a moderately high apartment building, and c) a high rise office structure. The three buildings are representative of those found in urban settings. They were selected because their variation in structure makes them amenable to the examination of a wide variety of behavioral dynamics.

Completing the report are the CONCLUSIONS and RECOMMENDATIONS. As is not unusual in the application of findings from research, gaps of knowledge also became evident here in the attempt to deal with management of people in crowded shelters and some suggestions are offered.

II. AREAS OF KNOWLEDGE
THE PHYSICAL, BIOLOGICAL, AND PSYCHOLOGICAL ENVIRONMENTS

Disasters strain everyone and everything. Property is damaged or destroyed, people are injured or killed, and the threat, duration, and consequences of these produce psychological stress, The dimensions of disaster cannot be spelled out exactly — the variations are much too extensive — but certain conditions appear to be basic and these are highlighted in this section.

The physical environment created by disaster is dealt with first. The impact of a nuclear detonation is severe and unpredictable. Although it is perhaps wisest to prepare protection for the worst event, a reasonable range of variables has been selected for this study and the behavioral solutions developed accordingly. Floods and tornadoes, as examples of natural disasters, usually are predictable in the probability of their occurrence but the form they eventually take and the extent of damage they produce are difficult to pinpoint in advance. Realistic variables have been developed from 1971 flood and tornado reports and behavioral solutions worked out for these.

The knowledge area of the biological environment in a nuclear disaster is dealt with next. This focuses upon the kinds and extent of injury which can be produced by the burst, i.e., the blast and shock, light and heat, and initial and delayed radiation effects. The nature of the biological damage is dependent upon the protection offered by the physical environment. A coverage of the more common injuries produced in conjunction with floods and tornadoes completes this discussion.

The psychological environment is extremely fluid in times of disaster. Behavioral descriptions are presented which cover the basic response patterns made by individuals and organizations in attempting to deal with disaster. Response usually will be according to ability in terms of past experiences, current perception of the disaster, and the presence or absence of basic resourcesfor carrying out desired actions. Effective communication is important in assisting individuals and organizations to cope with disaster and some notes on this are included in this section.

The Physical Environment

Nuclear Disasters

A nuclear disaster involves a tremendous explosion in which there is a sudden release of an incredible amount of energy in a small volume. The temperature rises dramatically to levels approximating those at the center of the sun. This produces the extremely high temperature which causes: a) air at the point of detonation to expand and move outward with incredible force and speed, b) a release of an enormous quantity of heat and light (thermal flash) which ignites combustable materials and produces burns of the skin at a distance of up to several miles. The nuclear transformation in the explosion produces initial radiation with latent radiation arising from radioactive dirt and debris which falls slowly to earth.

The nuclear explosion may be a high altitude burst, a low altitude burst, or may take place at ground level. All will have varying effects on the physical areas expected to shelter people. However, regardless of the type of burst, it will be necessary to provide protection for the shelterees from the intense light of the thermal flash, the heat and resulting fires, the initial nuclear radiation, and the over and underpressures which follow the blast. Finally, it is necessary to provide the shelterees with protection from radioactive fallout. The normal peacetime environment can be damaged dramatically by the blast wave, the heat, and the fire. Let us review the primary effects of each on material objects.

Blast wave. Most material damage in a nuclear burst is due directly or indirectly to the blast wave, the pressures involved, and the fires which may be created. Many variations in its effect are possible, including those brought about by weather and topography. For our purposes, peak overpressure in the nuclear disaster has been categorized as low (under 5 psi), medium (between 5 and 11 psi), and high (between 11 and 15 psi). Protection for the population will be discussed for these operational dimensions in preferance to using distance from the explosion, size of yield, and type of burst. How these interact for surface bursts is illustrated below.

Peak Overpressures - Surface Burst (psi)

Bomb yield	High (12-15 psi)	Medium (5-11 psi)	Low (under 5 psi)
1 MT	under 2 miles	2 miles	over 3 miles
10 MT	under 4 miles	4-6 miles	over 7 miles

Distance in terms of overpressure and yield

Five psi produces severe damage to most conventional structures and so becomes a critical figure in most damage estimates. It is accompanied by wind speed of about 160 mph. Under 5 psi, damage is variable but severe damage can occur at 3-4 psi. Glass breaks between 1/4 and 1 psi. Flying debris, including glass shards, are a source for secondary damage, becoming imbedded in other objects. Pressures between 5 and 11 psi will produce much more extensive damage — at 9 psi, for example, a railroad car can be completely destroyed. Although destruction increases with the increase of overpressures, it is interesting to note that analysis of Hiroshima data showed buildings (and some people in them) were able to survive in overpressures of 20-30 psi.

Thermal flash. The heat and fire are most destructive although most material damage is caused by the fires started by the intense heat. Heat from a one megaton bomb can ignite materials 12 miles away. Fires are started wherever materials will ignite — residential areas, industrial buildings, grasslands, etc. Generally, the better the quality of a home, a building or a neighborhood, the greater will be the chances of being fire-resistant and hence, spared of fire. Fire is a hazard which persists for many hours and can affect enormous areas.

Radiation. Nuclear radiation, per se, produces minimum change in the physical environment; its damage is primarily biological which is the focus of the next section.

Natural Disasters

Floods. A flood is an overflow of water into an area not usually submerged and is usually caused by an excessive amount of rainfall beyond human control.

The greatest physical damage from a flood probably results from the sheer force of the water as in the destruction of dams or overflowing of streams which, in turn, release water to go into the streets, homes, stores, etc. Communications and travel can be severed; food, water, and power supplies can become unavailable; a problem can occur with sewage treatment; and so forth. An outbreak of fire can result in total destruction inasmuch as firemen often cannot get to the blaze. In addition to becoming inundated, roadways can be washed away or have other object washed onto them, such trees, rocks, and mud. In coastal areas flooding is often associated with high tides that usually accompany severe storms.

River engineering in the United States now has most of the normal rate of flow of water under control and river watches are able to predict and control normal excesses. Most often it is the unique storm formations and flash flooding that result in disaster.

Tornadoes. A tornado is a violent windstorm in which there is an upward rush of air that is replaced by new air forming a whirl as it is deflected by the earth's rotation. Tornadoes occur over land, especially in the Middlewest.

A tornado may destroy a building in the following manner: pressure outside the building drops drastically while the pressure inside the building remains the same. A low order explosion may occur when sufficient equilibrium has been destroyed. In addition to the building being damaged, flying debris can cause considerable secondary damage. The suction caused by the windstorm pulls the debris along with it, adding and dropping as its long funnel shaped cloud moves along as it creates a path of destruction. Other damage results from objects being blown away, struck by other objects, or disintegrated by the force of the pressure.

Examples of the Physical Environment

Three buildings have been selected as representative of structures typically found in urban areas of the United States where people may already be or may go for shelter. The buildings selected are a modern school building, a moderately high apartment building (nine story), and a high-rise office structure. They are illustrated in Figures 1-14 in the APPENDIX.

1. A School Building

The school building is typical of those built in many communities in the United States during the last twenty-five years, being a one to three story structure with a great deal of fenestration. The school has a reinforced concrete structural frame, with floors being of 2-1/2 inch concrete on precast "T" sections. All ceilings are acoustical tile. Exterior walls are 4 inch face brick or stone backed by 1 inch of rigid insulation and 8 inch concrete block. The roof is built-up tar and gravel over light weight concrete topping the precast concrete "T's". All glass is 1/4 inch heat absorbing plate. The school contains approximately 53,000 sq. ft. of floor area with 30,000 sq. ft. being on the first floor, 14,000 on the second floor and 9,000 on the third floor. The building has used blast

slanting* in its design as one means of increasing shelter space within its exterior walls. The blast slanting is achieved by bringing the outside ground level to sill height (3 feet) on the south and west walls.

2. An Apartment Building

The moderately high, nine story, building is again typical of dwellings found in urban areas. The construction is a reinforced concrete frame with concrete block, precast concrete, cast in place exterior walls and interior partitions. The floors and the roof are of concrete beams, cast in place with concrete one-way ribbed joist. Slanting techniques have been used to provide 95 additional spaces for fallout shelterees on the first floor. There is 5,940 sq. ft. of area per floor.

3. A High-rise Office Structure

The high-rise office building is representative of those being constructed in urban areas. It is of steel frame construction with poured concrete pan floors and precast concrete (curtain) walls. The interior partitions are moveable metal and it has a poured concrete roof. The construction also features a full area basement and sub-basement with poured concrete walls.

Shelter Availability in the Buildings

1. A School Building. As a result of blast slanting being used in the design and construction the building contains 2,792 shelter spaces based upon a protection factor of at least forty (see Figures 2 and 4). However, protection would be almost non-existent under blast pressures of 15 psi or even 7 psi because of the effects of the burst's thermal pulse and resulting fires, and from the pressures and resulting sprays of glass, building parts, and general debris.

A close examination of the school building shows that protection from modest forces (under 7 psi) would indicate the availability of 7,420 sq. ft. in the internal core of the first floor as the best area for protection from the direct effects (see Figure 2). The floors above this area would help to absorb a portion of the effects, thus offering some protection to the ceiling in this area. The reinforced concrete structure should survive a blast of this magnitude and theoretically shelterees would be sufficiently protected in this internal core. However, recently published research shows

*The slanting implies the inclusion of protection in the design of a building at little or no extra cost and without loss of any function planned for that building.

that this kind of area would not offer nearly as much protection as original calculations would indicate, since the many doors and other openings would greatly diminish the shielding effect of the exterior walls and the interior partitions. Maximum protection would be offered if shelterees were able to be in a prone position but this would mean fewer than 800 persons could be accommodated. Under conditions of considerable crowding (3 sq. ft./person), approximately 2,500 shelterees could be accommodated in this central core (vs. the total of 2,792 allowed throughout the entire structure at 10 sq. ft./person). Also, providing adequate ventilation would be impossible for 2,500 shelterees, figuring 15 cfm/shelteree, for longer than perhaps 30 to 40 minutes. If the burst were of 2 psi or less intensity, shelterees in the central core would be safe from the direct blast and a prone position would not be necessary. Thus, it would be possible to locate greater-than-allocated numbers in the central core area for a very short period of time during the blast and thermal pulse phases of an intense burst and then to relocate for safety during the fallout phase.

During the fallout phase (see Figures 2 and 4) most areas 30 feet or more from windows and other openings would provide protection based on a protection factor of forty. This would provide space for 2,792 shelterees which is about 10% greater than the school's normal population. In addition to having adequate space, the use of this school for fallout protection is especially suitable since it has an emergency generating facility (propane gas) which could provide light and possibly even heat.

In the case of a natural disaster such as a tornado the same areas (30 or more feet from windows or other openings) as indicated for fallout protection would be available (see Figures 3 and 5). With reinforced concrete construction and flat (built-up) roof, the shelter offers protection in tornadoes with glass and openings the primary sources of damage. The school could thus accommodate 2,792 shelterees @ 10 sq. ft./person or many more with crowding. Following the tornado's windstorm, the entire 53,000 sq. ft. area could be used for shelter, again with the added advantages of auxiliary light and heat.

Assuming the school to be above the level of flood waters, the entire 53,000 sq. ft. of space (see Figures 3 and 5) would offer shelter to those evacuated from flooded areas. Once again the availability of auxiliary light and heat as well as cooking and eating areas would make the school a prime shelter area.

2. The Apartment Building. The apartment building would provide excellent fallout protection for approximately 2,500 shelterees. The use of slanting techniques in construction provides 950 sq. ft. on the first floor (95 shelterees) @ 10 sq. ft./person plus approximately 3,020 sq. ft. per floor on floors 2 through 9. This is considered excellent fallout protection due to the reinforced concrete construction, the adequate ventilation with windows open or removed and the availability of battery operated lights in the event of failure of electric utilities. (See Figures 7 and 9.)

The apartment would provide above average protection against blast conditions for 735 people at 10 sq. ft./person or under crowding (3 sq. ft./person) would shelter 2,450 persons. This is based on 950 sq. ft. on the first floor (slanting techniques used) with 800 sq. ft./floor on floors 2 through 8. The ninth floor is not included because direct effects of blast could loosen roof beams and drop debris onto the ninth floor. This building offers above average protection from the effects of blast and the thermal pulse considering the entire area is above the ground. This is because the precast concrete and the concrete block outer walls should absorb a great deal of over and underpressure from the blast, with the concrete and the cast-in-place concrete intercore partitions providing additional shielding from the direct effects. A limitation is the large number of openings in the exterior walls and the number of openings in the interior partitions. The limited number of openings in the interior would seriously restrict the amount of natural ventilation and would limit both the number of people who could be sheltered under conditions of crowding and would limit also the amount of time that people might be sheltered under conditions of crowding. (The areas of protection from the effects of the blast and the thermal pulse are shown on Figures 7 and 9.)

This apartment building could provide shelter for up to 4,500 persons (500/floor) if the building were above the flood water level. Even if the building were in a high water area the upper floors could be utilized as a shelter area. The structural portions of the building should withstand high water.

In the event of a natural disaster, such as a tornado, all areas thirty or more feet from the perimeter of the building would offer protection. This building would provide shelter for more than 2,500 persons. As was a case with the school building, the auxiliary lighting system would be an

additional asset for the shelterees. Figures 8 and 10 designate those areas which provide shelter against tornados as well as shelter space available in times of flood.

3. The High-Rise Office Building. The office building provides a large amount of protection from fallout. Figures 11 and 13 designate the areas. The prime safety areas of the basement and sub-basement will accomodate 7,430 people while the inner core of the above-ground floors, with the exception of the top (15th) and the first floors, will provide shelter for an additional 8,745 people. The total useable floor area for fallout protection is calculated to be 161,752 sq. ft.

Of the three buildings, the high-rise structure offers the best protection against blast. The basement and the sub-basement areas are able to provide shelter space for 7,430 people. With the use of supplementary ventilation equipment the number of shelterees who could be accommodated could be expected to double. It would not be advisable to ,e any of the areas above grade for blast protection. Moveable metal interior partitions, curtain wall exterior construction with more than "two acres of glass" makes this entire area unusable as protection against blast.

The steel frame building, resting on a reinforced concrete foundation should withstand most flooding. Since the area on floors 2 through 15 is so extensive, no thought has been given to using the area on the first floor or below grade. More than 100,000 people could be given shelter from flood or high water on the upper floors of the high-rise office building.

Just as the basement and the sub-basement area offer excellent shelter from the effects of a nuclear blast, so would they offer excellent protection from the pressures of a tornado. Figures 12 and 14 indicate that this area could be fully utilized for shelter from a tornado and also indicate that floors 1 through 15 of the building, with their "acres of glass" and moveable partitions, should not be used.

The Biological Environment

The purpose of this section is to assemble relevant biological information for subsequent integration with the identified parameters of protection from the effects of blast and fallout delineated in the previous section. Knowledge, in the form of a base line, becomes important information when dealing with remedial or preventative measures to counteract the elements

in the hostile physical environment. The base line, designating what man can endure during normal and stress conditions, serves as a reference point in dealing with the behaviors required to take appropriate action and also makes it possible to infer whether an individual's problem source is physical or psychological. This section presents a summary of the knowledge relating to man's biological limits within which survival can occur. The key issues felt necessary for this study have been selected and are presented in summary form.

Nuclear Disaster

In a nuclear disaster, blast, thermal radiation, and nuclear radiation are the three major sources of biological damage accompanying a nuclear detonation. In general, the type of injury and the degree of severity again are dependent upon a variety of circumstances — the distance away from the hypocenter, the explosive yield of the bomb, and the amount or density of the shielding.

Blast produces two types of injuries: direct which are caused by the characteristic high pressure and indirect which are caused by the missiles and body displacement. Three parameters of the blast wave determine its effects: the rate of pressure rise at the blast wave front, the peak overpressure, and the duration of the positive phase of overpreasure. Nuclear explosives have a fast rise time which increases the probability and the severity of the injury. The main factor determining injury potential is level of the peak overpressure.

Internal organs are highly susceptible to the effects of blast. The sudden compression and decompression of the body following the blast wave may seriously damage different organs or areas, particularly those which have variations in density. The lung is quite susceptible to hemorrhage and edema (liquid extrusion) because of its liquid and gaseous phases. Air embolism, frequently causing irreversible damage to the heart and brain, results if the injury is severe. It has been found that the threshbld for lung damage is an overpressure of about 15 psi. Rupture of the eardrum is also a consequence of overpressure and that threshold has been established at 5 psi, with a 50% probability of rupture varying between 20 and 33 psi. Figure 15 shows the thresholds for ear and lung damage which depends upon yield of the explosion and distance from the hypocenter.

RANGE-YIELD RELATIONSHIP for
INDICATED PRIMARY BLAST DAMAGE; SEA-LEVEL SURFACE BURSTS

Applies to Fast-rising Overpressures with Ideal or Near-ideal Wave Forms

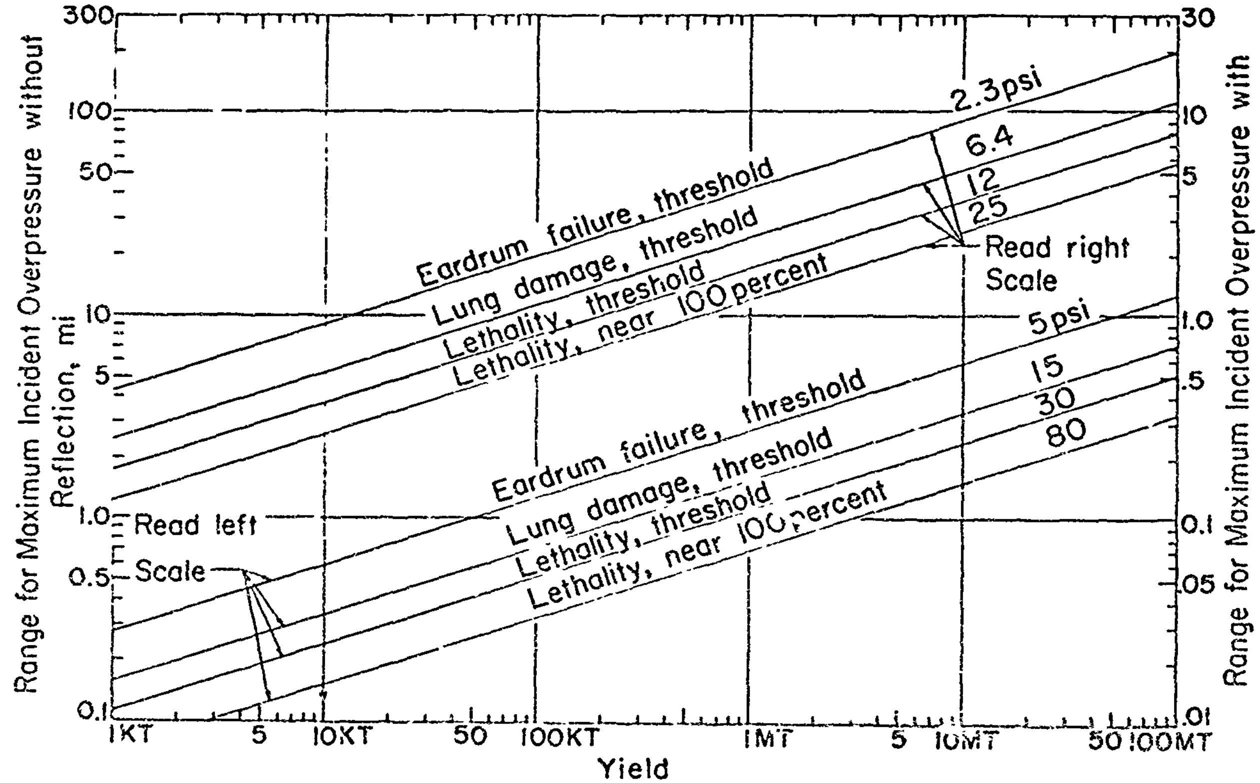


Figure 15

Source: "The Environmental Medical Aspects of Nuclear Blast," White, C. S., Bowen, I. G., and Richmond, D. R., 1962.

Indirect blast injuries are those associated with the impact of missiles or the displacement of the body. Injury from the first type depends upon the impact velocity and angle, the size, shape, density, and mass of the moving objects, generally blast debris. But the portion of the body involved in this impact is also an important consideration in the potentiality of damage. Figure 16 displays thresholds for 10 gm fragments of glass for varying yields and distances. The threshold for skin lacerations has been found to be 50 ft./sec. and the threshold for serious wounds is 100 ft./sec. A threshold of 15 ft./sec. is associated with the impact of a non-penetrating 10 lb. object producing cerbral concussions or skull fracture.

The second type of indirect blast injury, physical displacement of the body against a hard surface, depends upon the high velocity winds accompanying the blast wave. The body must be moving at least 10 ft./sec. for a translational distance of 10 feet to produce injury. For a skull impact injury to produce death, the body must be moving at 20 ft./sec. Figure 17 shows the range-yield relationship for producing impact damage to a 165 pound man.

Thermal radiation from the explosion is another major source of bodily injury. Flash burns occur at a high frequency due to thermal radiation itself and also hot gases and dust associated with the high pressures. Flame burns are not uncommon because of the high incidence of fires near the hypocenter.

Burns produced from thermal radiation can be direct (from the absorption of the radient energy by the skin) or indirect (as a result of fires produced by the radiation). The energies required to burn exposed skin are related to explosive yield. If a given amount of energy is applied quickly, a more severe burn is produced. Consequently, more energy is required from a larger yield explosion than a smaller yield to produce a burn of the same severity. Figure 18 shows how explosion yield and distance from the hypocenter affect the thresholds for first and second degree burns. Thermal radiation can produce flash blindness and retinal burns as far away as 35 miles from a night detonation of a 20 KT nuclear device when the pupil of eye would be at its maximum dilation.

Nuclear radiation is another major source of injury to be reckoned with. Initial nuclear radiation occurs along with the thermal flash and produces acute doses. Delayed nuclear radiations from fallout persist for longer times and are termed chronic doses. The same dose rate would produce greater injury in an acute exposure than spread out in time in a chronic exposure.

RANGE-YIELD RELATIONSHIP for INDICATED TERTIARY BLAST DAMAGE to 165-lb AVERAGE MAN* for SEA-LEVEL SURFACE BURSTS

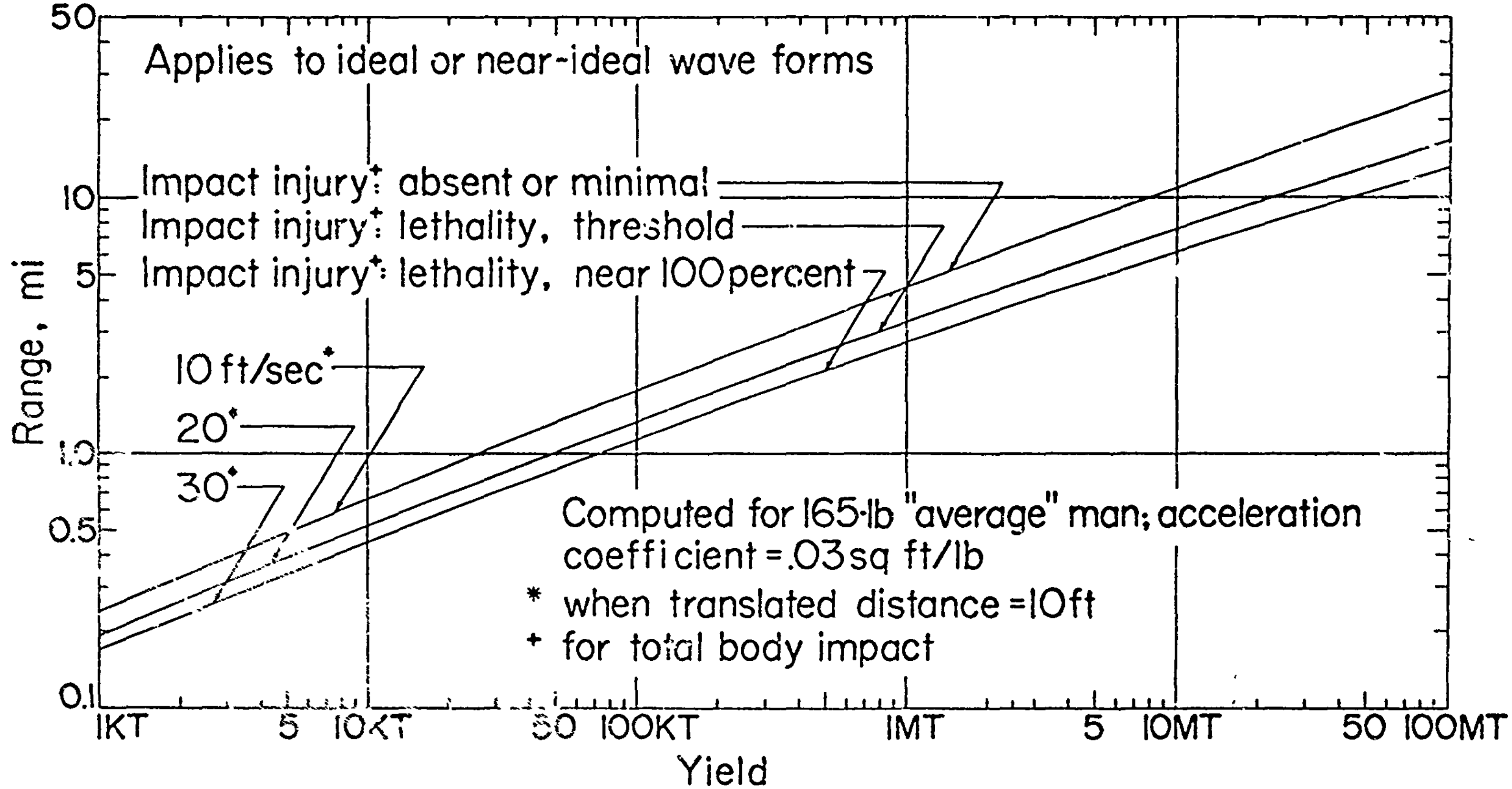


Figure 16

Source: "The Environmental Medical Aspects of Nuclear Blast," White, C. S., Bowen, I. G., and Richmond, D. R., 1962.

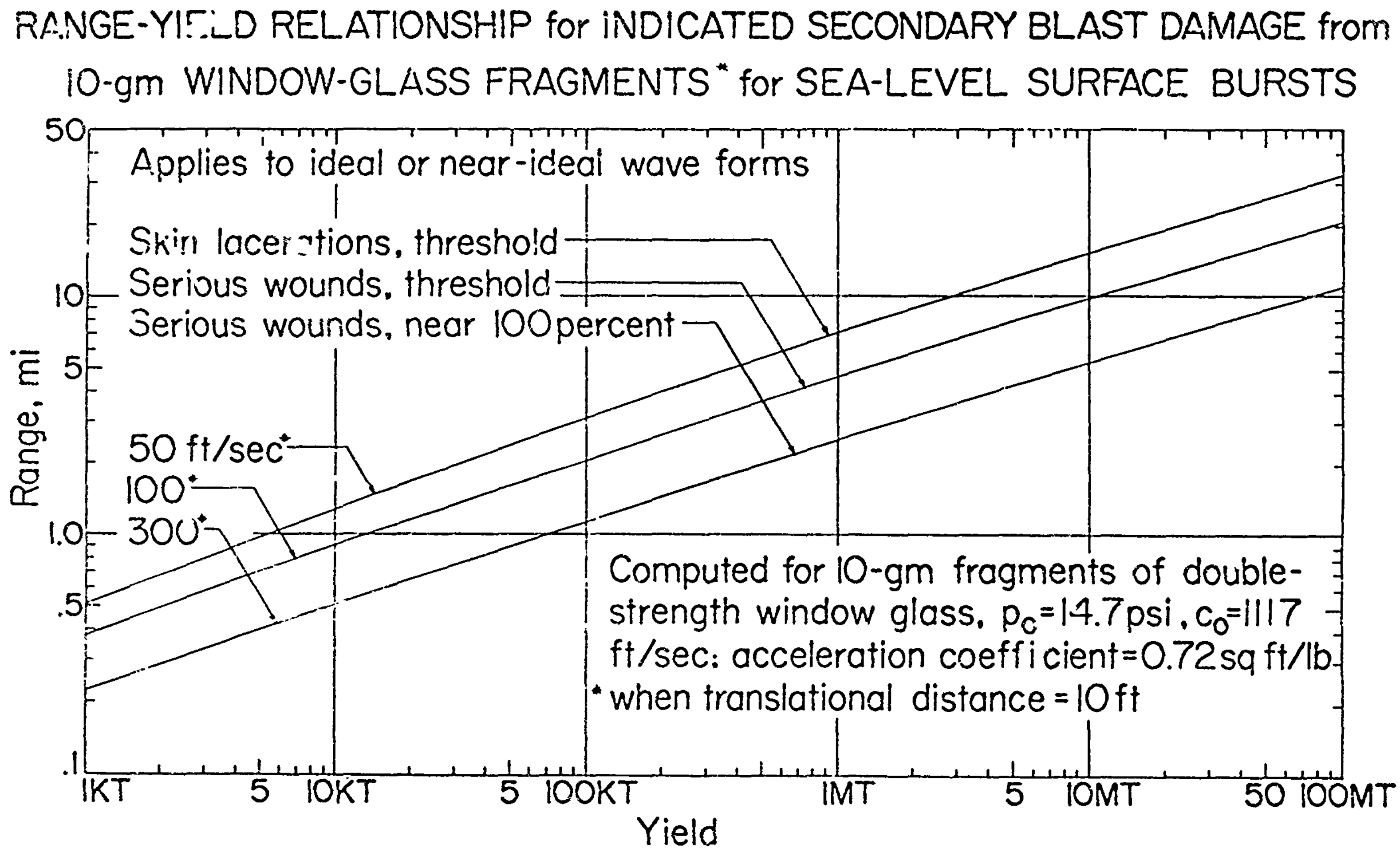
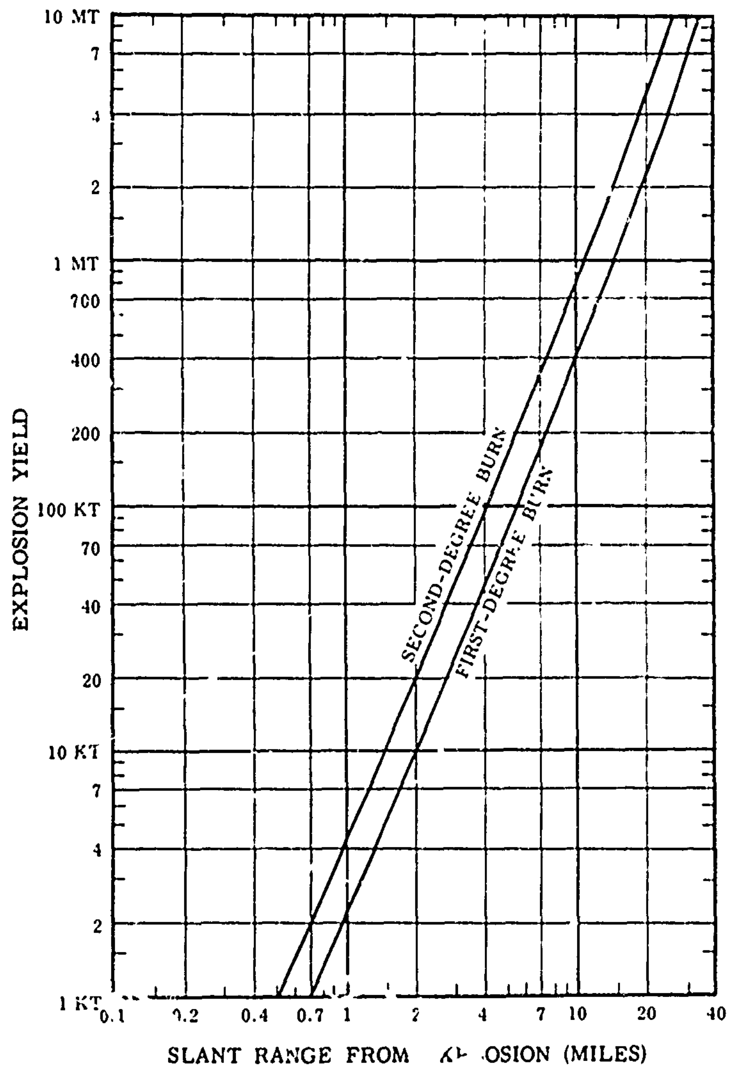


Figure 17

Source: "The Environmental Medical Aspects of Nuclear Blast," White, C. S., Bowen, I. G., and Richmond, D. R., 1962.

BURN INJURIES



Ranges for first- and second-degree burns as a function of the total energy yield.

Figure 18

Source: The Effects of Nuclear Weapons, p. 573

Bodily damage from nuclear radiation is from the ionization of living cellular tissue, sometimes altering or destroying cell constituents necessary for normal functioning. For our purposes, the rem is used as the radiation measurement because it is the dose unit of biological effe.... Figure 19 shows how the range varies with the energy yield for 100, 500, and 1,000 rem doses. The degree of radiation damage is dependent upon the extent and part of the body exposed, the amount absorbed and the rate of absorption. Far-reaching effects begin above 100 rems; nausea and vomiting, discomfort, loss of appetite, and fatigue are the earliest symptoms and may occur the first day or so following exposure. A latent period of several days to two weeks may mask serious injury which is occurring internally even though the person experiences little or no discomfort.

A person exposed to 200 rems should be admitted to a hospital and should respond positively to treatment. Beyond 600 rems there is considerable uncertainty and variability in response and following a 1,000 rem dose the patient's recovery is doubtful. Figure 20 summarizes the clinical effects of nuclear radiation exposure.

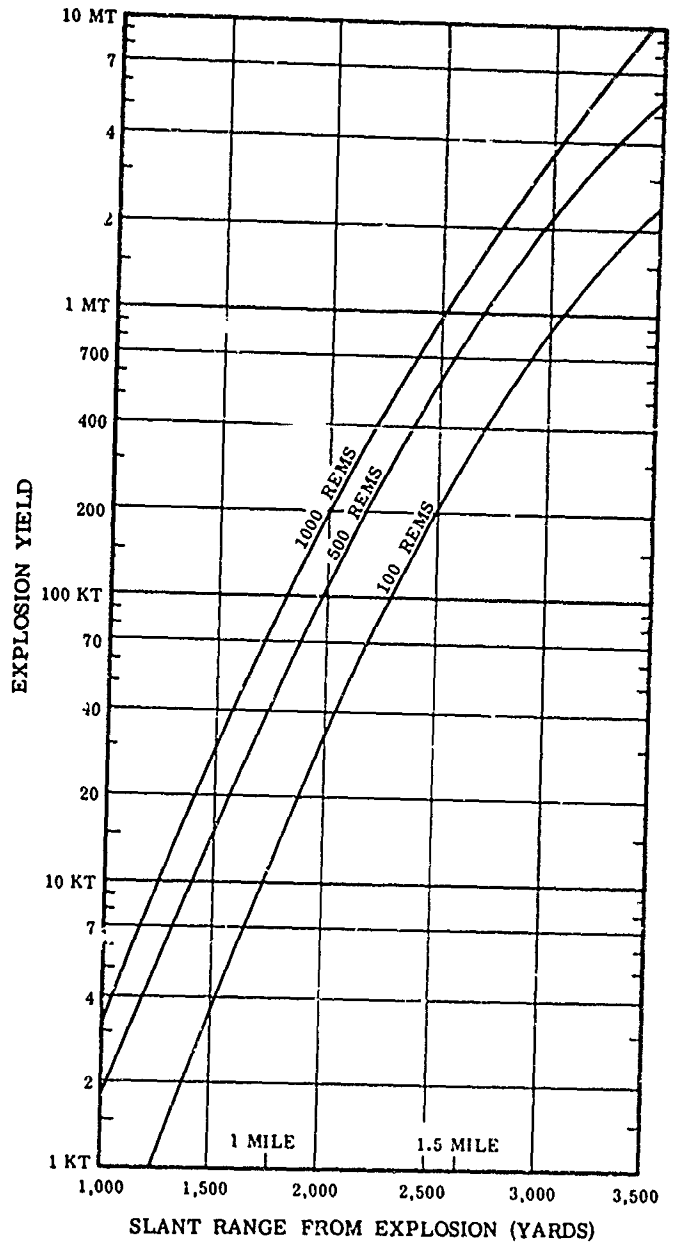
Radiation effects likely would occur to people already injured from blast and/or thermal radiation and these injuries would compound the bodily damage and complicate recovery. The combination of nuclear radiation exposure and thermal burns will produce greater and earlier bodily shock; in addition, wounds would be slower to heal since the body has been rendered more susceptible to infection and less able to deal with it.

Potential injury from a nuclear explosion should not be underestimated. The potential effects are so great that many lives could be lost outright, others linger on before dying, while for others recovery could be very slow. Thus, it is important to maximize physical protection for people and to induce them to use it so these harmful potentials are not reached.

Natural Disasters

Floods. Drowning always presents a hazard where bodies of water are concerned, In floods, people who can swim are swept away by strong currents of water. There are many other sources for injury and death. Drinking contaminated water, being struck by debris, and coming in contact with live electric wires are quite common.

Tornadoes. Injury during a tornado generally accompanies the explosion. Often the person is hit by flying debris or he can become part of the cloud



Ranges for total doses of 100, 500, and 1,000 rem of initial nuclear radiation as a function of the energy yield.

Figure 19

Source: The Effects of Nuclear Weapons, p. 584

SUMMARY OF CLINICAL EFFECTS OF ACUTE IONIZING RADIATION DOSES

Range	0 to 100 rems Subclinical range	100 to 1,000 rems Therapeutic range			Over 1,000 rems Lethal range	
		100 to 200 rems	200 to 600 rems	600 to 1,000 rems	1,000 to 5,000 rems	Over 5,000 rems
		Clinical surveillance	Therapy effective	Therapy promising	Therapy palliative	
Incidence of vomiting	None	100 rems 5% 200 rems 50%	300 rems 100%	100%	100%	
Delay time	—	3 hours	2 hours	1 hour	30 minutes	
Leading organ	None	Hematopoietic tissue			Gastrointestinal tract	Central nervous system
Characteristic signs	None	Moderate leukopenia	Severe leukopenia, purpura, hemorrhage; infection Epilation above 300 rems		Diarrhea fever; disturbance of electrolyte balance.	Convulsions, tremor; ataxia; lethargy.
Critical period post-exposure	—	—	4 to 6 weeks		5 to 14 days	1 to 48 hours
Therapy	Reassurance	Reassurance, hematologic surveillance	Blood transfusion; antibiotics	Consider bone marrow transplantation	Maintenance of electrolyte balance.	Sedatives
Prognosis	Excellent	Excellent	Good	Guarded	Hopeless	
Convalescent period Incidence of death	None None	Several weeks None	1 to 12 months 0 to 80% (variable)	Long 80 to 100% (variable)	— 90 to 100%	
Death occurs within	—	—	2 months		2 weeks	2 days
Cause of death	—	-	Hemorrhage, infection		Circulatory collapse	Respiratory failure; brain edema.

Figure 20

Source: The Effects of Nuclear Weapons, p. 591

and can be picked up and dropped or thrown. Less serious injuries result from being knocked down or against something.

The Psychological Environment

The psychological environment is the milieu in which behavior takes place. The environment created by disaster is much different than that of normal times in that it produces stress of a severity and quality not generally encountered. Responses, as attempts to understand and then to deal with the many dimensions of the disaster, will take a wide variety of form and expression. And, many of these can be considered normal behavior under conditions of disaster induced stress.

Let us first discuss the concept of psychological stress and then review briefly the basic response patterns in terms of the time stages a disaster presents. Following this, the psychological environment of the individual will be extended to include the organizational aspect.

Psychological Stress

Individuals faced with the emergency conditions occasioned by disasters undergo severe stress. In brief, this is a state of upset which causes the body to mobilize its resources and to burn more energy than it normally does in order to cope with the stress producing event. An important aspect of stress is that its emergence depends upon the anticipation of something harmful in the future — a situation is interpreted as being personally threatening. Depending upon the degree of danger each believes it holds for him, a particular situation can be perceived as threatening by one individual and not by another.

Psychological Responses According to Time

This discussion will examine the behaviors which are characteristic before, during, and after a disaster. The variations in human responses are presented in the section which follows but have relevance here.

Pre-impact Phase. Behavior preceding a disaster should include preparation for effective reactions during the periods of danger. An individual should learn about the different kinds of dangers inherent in nuclear and natural disasters and put this knowledge to use through practice. He will then be ready for action when disaster comes and be more likely to respond with prompt and effective behavior.

Warning. When a disaster occurs there may be little or no warning. If present, the warning may result in either constructive behavioral responses or in disorganizing ones. Actions will tend to be constructive when a) adequate preparation has been acquired during the pre-impact phase; b) there is appropriate training for proper actions in the warning interval; c) there is time during the warning period to respond as needed; and d) all individuals to become affected by the disaster receive the warning signals.

The warning signals should be of a nature to produce discomfort so that people are aroused sufficiently to take action. The action then should be directed toward accomplishing specific lifesaving objectives and should be carried out within the time limits of the warning interval—usually quickly! Indecision and disorganized behavior pay heavy tolls here — hence, the need for pre-impact preparation for emergency behavior.

Threat. Threat indicates perception of a change in conditions which indicate to a person that local and personal danger are present. It actually begins during the warning phase and continues into later phases. During conditions of threat, much variety in behavior is found. Behavior will be constructive and organized if the person knows what actions to take and begins to take them.

Impact. This is the time when disaster strikes and all attention should be directed to withstand the full force of the disaster. Some emotional response can be expected, e.g., rapid respiration, trembling, inaction, etc. It is normal to react overtly to distress.

Immediate Post-Impact. Effective behavior may be difficult to attain and maintain during the impact period but does become possible after the destruction of the impact period has subsided. This is a critical period. It is important that people return to normalcy as soon as possible. Immediately following the impact period, that is, after the disaster or emergency producing situation has diminished or concluded, some people may be unable to move, think, or be concerned about themselves or others. This is to be expected; however, only when such behavior persists unduly can it be considered serious and require attention. Some require more time to recover than others and frequently need emotional support, special help, or assistance. And, if injury has occurred, physical needs may require attention at the same time, complicating recovery from the disaster-induced stress. This is also a period of inventory — people are determining the extent of the damage as it relates to them. Hence, new stresses are possible.

In evaluating another's behavior, it should be kept in mind that a person will be responding in the best way he knows. If his actions appear ineffective, they may actually be ineffective, but it is the level at which he is able to respond. Fortunately, individuals are highly receptive to suggestions at this time and others who have the situation in hand and possess the skills and knowledge necessary for constructive action should share that generously with the less fortunate.

Again, this is an important period for effective lifesaving action. Where confusion and disorganization dominate there are increased fatalities, a greater incidence of injuries, and the seeds of hopelessness are sewn. Leadership behavior should provide guidance in the initiation of recovery. Unless a strong communication system is underway with the outside community, leadership will have to come from within the disaster group — outside help comes a little late for maximum effectiveness.

Late Post-impact. Danger is now completely over and people are returning to their normal way of living. If the disaster has been severe and rescue is necessary, it takes place during this period. People from outside the disaster area now can enter it safely. In natural disasters too much help sometimes arrives, help which is misguided and can be competitive. Roadways can become clogged with curious sightseers and hamper rescue operations. Inter-organizational communications are important here if rescue operations are to be efficient and effective.

Individuals and communities hasten to recover from a disaster. Behavior during the recovery period will depend on many factors: the nature and intensity of the disaster, the number and type of physical and emotional casualties; the facilities and personnel which have been available, to name the most important. Psychological recovery is dependent upon these.

The distinct phases or stages into which most disasters fall have been highlighted. Now let us look at typical patterns of individual responses to disaster induced stress which can be expected. The behaviors usually do not fall clearly into one pattern or another; rather, these serve to demonstrate dominant behavioral patterns.

Individual Behavioral Response Patterns in Disaster-Induced Stress

Three major behavioral patterns evidence themselves in normal individuals undergoing stress in disasters: normal reactions, depression or withdrawal reactions, and hyperactive responses. (Problems of neurotic and psychotic individuals are beyond the scope of our discussion.) Ideally, in

a dangerous situation each individual should understand what is happening, its significance, and what appropriate actions to take.

Normal Reactions. Few individuals are able to remain calm and under complete control. Most people show stress reactions overtly. They may tremble, their knees shake, tears may appear, they may weep openly, perspire excessively, feel weak in the knees or stomach, become nauseated and hot, speach may be disconnected, thoughts unorganized, and so forth. Each person will responddifferently. But all are normal reactions to danger. They are temporary. They serve to alert us to action. They are our body's signals that something is or may be wrong and is its way to prepare for unaccustomed action. Fortunately, most people regain composure shortly and adapt to the situation as required and these "signals" terminate.

Depressed or Withdrawal Reactions. People who appear to be completely unaware or detached from a dangerous situation are experiencing a depressed or withdrawal reaction. They seem puzzled or preoccupied with the disaster. They may gaze vacantly into space, may not respond when spoken to, or may stand or sit quietly in the midst of the danger. These people cannot respond and are unable to help themselves or others. Their first step toward regaining their normal behavior, once contact with reality is re-established, will be to become busy with some quiet activity which can be done by rote, i.e., without thinking. Others will have to assist them in initiating their recovery. The rote or mechanical activity can spread to simple tasks carried out under direction and supervision, followed later by assuming responsibilities when the person is ready. These are normal people using abnormal behavior responses temporarily under the circumstances of stress. The sooner they can return to their normal behavior patterns the better it will be.

Overactive Responses. Some individuals become overactive. They become excited, talk rapidly, joke, make endless suggestions and demands. They appear capable and confident and may seem to be leadership material. However, their behavior is purposeless and disorganized. They jump from task to task at the slightest distraction and create confusion for others. These individuals frequently interfere with the effectiveness of establishing leadership. Normal composure can be achieved for them through guided activity. Since they have a need to be active, their energies should be directed toward tasks requiring physical activity. As they return to normal, they can be

given greater responsibilities. Working creates opportunities which contribute to the well being of others and to their own self-confidence.

Most often, individual response to the stress of a disaster should be allowed to dissipate without interference. Emotional support and other help should be offered and a return to normalcy will be forthcoming. When inappropriate patterns persist, or when these patterns interfere with the functioning of the group, corrective measures should be initiated.

An individual's behavior is also dependent upon the behavior of others. The next discussion reviews the components of individual and group behavior within organizational structure.

Individual Behavior within the Context of Organizational Structure

Organizational structure can be viewed in a framework of three major components: a) the people who member it (participants); b) people/organization motivations (goals); and c) the organizational structure. Each will be discussed in terms relevant to possible shelter organization.

The People (Participants). Regardless of the purpose of an organization, individual characteristics differentiate the people involved and become important determiners of the behavior which will occur. For the purpose of examining an individual's behavior within an organization, four basic categories are offered: survival and social needs; personal resources; personal experiences; and personality.

The survival and social needs are reviewed first. These needs motivate behavior and must be identified if behavior is to be understood. Examples of the basic needs of survival are air, water, food, etc. Examples of security needs are housing, clothing, etc. When these needs are met, an individual will look to other people to satisfy his social needs. Some of the social needs are met by receiving from others such things as attention, praise, friendship, etc., while other social needs are met by giving to others such things as help, love, friendship, etc. To meet the social needs it is important that the person possess the necessary social skills to interact appropriately with other people. The level of need and the combination of needs vary from individual to individual and culture to culture.

Physical, cognitive, and social abilities are three kinds of personal resources central to behavior. Physical resources result in ability to perform manual tasks. Cognitive resources enable a person to process information and to solve problems. Accumulated knowledge and gained experience are

processed to be used appropriately. Social resources are the social skills required for effective interaction with other people. A person's behavior will draw on various combinations of these resourses according to the way he perceives a given situation.

An individual's personal experiences serve as a basis for evaluating new situations and facilitating his behavior in them. Greater competency in dealing effectively with the demands of an environment result from the amount an individual has previously applied and practiced his knowledge and skills. Knowledge is important only if it can be used when needed and, in this sense, an individual's resources are built on his experiences.

Finally, each participant brings with him into the group, a personality, patterns of behavior which dominate his responses to his environment. He has built up a repertoire of actions and habits and will not readily discard them.

The foregoing contribute to the variations in behavior that can be expected of the participants (the shelterees) in emergency situations. When, how or whether an individual will respond depends upon these characteristics and upon his perception of the situation. His perception of the situation and his choice of response may be influenced by the characteristics of the organization. Individuals entering a shelter will bring with them considerable knowledge and skill which can be drawn upon for the successful management of the emergency situation.

People/Organizational Motivations (Goals). Needs common to group members will develop and maintain group unity. If these needs are congruent with those of the organization (the goals of civil defense) successful actions can be expected and the lifesaving goals may be achieved. In a shelter it is likely that incompatible goals will not be a problem inasmuch as people coming to a shelter will be doing so for their protection and expect to obtain help from the shelter management. After the danger period, conflicts may arise when personal needs make demands that differ from those of the organization. For example, people may want to leave to check their homes or loved ones before shelter management indicates this is possible.

Structure. An organization attempts to achieve its goals through its people and provides a structure for this. In an industrial setting, individuals work together according to certain rules and guidelines, programs and constraints. If lifesaving goals are to be reached in the shelter situation, the shelterees must respond similarly to the structure already set up for them or adapt it to their needs.

Actually, the people sheltered are not even a group, much less an organization when they arrive at the shelter. They will be required to form a group instantly. In addition, they may be unsure of their own or the govenment's motivations and may be unfamiliar with roles to play and actions to take. Hence, they will require considerable instruction to first form an organization, a group. At this time they must be told what to do to create the organizational structure necessary for interaction. Only after the structure has emerged can resources be utilized.

It is important to note the effort industrial organizations make to promote communication. They are aware that information must flow throughout the organization. Space may limit communication flow in a shelter but it still is necessary for shelterees to obtain information. Their needs include receiving instruction and attaining emotional stability. Individuals who know that to expect are willing and able to endure and to adapt to a stressful situation. As in an industrial organization, shelter management will use communication to obtain information for its decision-making.

If a system for communication in a shelter does not provide proper and sufficient information, then an informal system will arise with the resulting distortion of fact, coupled with rumor. Information should be given the shelterees regularly by people with credibility.

The forgoing discussions in this section serve as a knowledge basis for the behavioral problem and its resolution, which are presented in the next section.

III. THE PROBLEM AND RECOMMENDED SOLUTIONS

The problem posed for study concerns setting up procedures for maximum capacity loading of buildings in the case of a nuclear or natural disaster. A nuclear disaster would require protection from the effects of a nuclear detonation, i.e., the air blast and ground shock, the light and heat of the thermal pulse, and the initial and delayed radiation. Protection during the natural disasters of floods or tornadoes centers on excessive quantities of water or wind.

The procedures set up for using the shelter protection potential of the three representative urban buildings are presented in the form of models and case studies. Two models for locating people (i.e., the physical placement of people within a group within the shelter area) during the periods of danger are shown in Figure 21 and Figure 22. These models then are applied to the buildings. Implementing the scheduling of the people according to place and body position is discussed next. A concluding section summarizes the behavioral objectives to be accomplished by the scheduling and placement procedures selected. Use of these procedures is recommended to resolve the problems of maximum utilization of protection facilities offered by shelters.

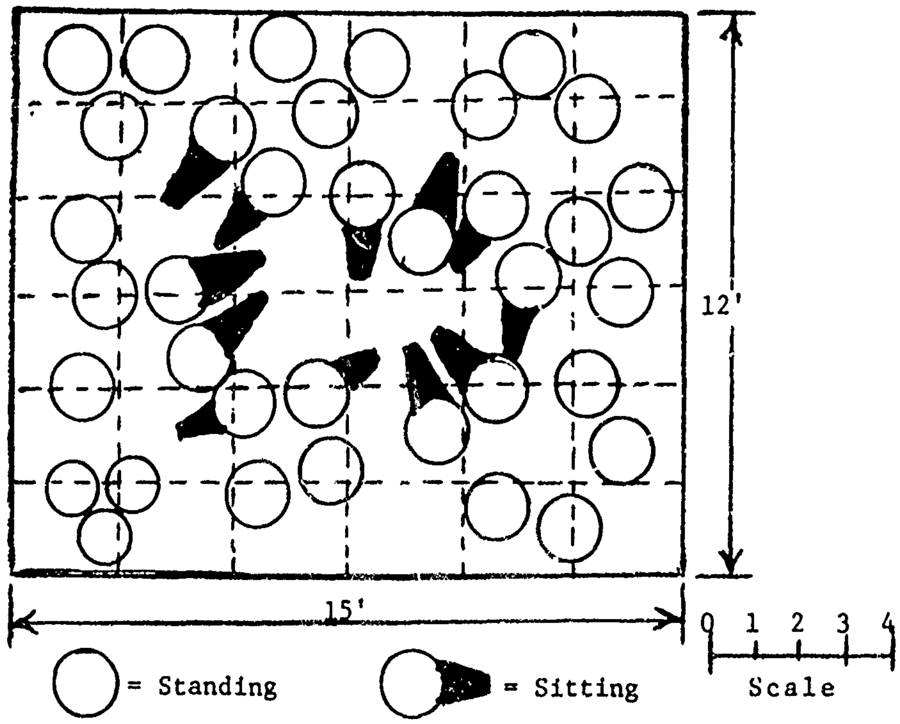
Models for the Placement of Shelterees

The model presented in Figure 21 shows the physical placement of people within a group for protection during short term confinement. This period is expected to be about an hour long but our model has been designed for use up to about six hours. Placement would be during severe conditions, primarily those produced by the light and heat of a nuclear thermal pulse and by the over and underpressures of the blast. This model could also apply to overcrowding for protection from excessive winds.

In the placement model for short term protection, Figure 21, people have been put in groups of 36 (three dozen) and alternate between sitting and standing positions. Approximately 1/3 of the group should sit and 2/3 should stand. Thus, at any one time, approximately 12 people (one dozen) in the group should be sitting and 24 people (two dozen) should be standing. Ten minutes spent sitting is followed by 20 minutes standing. The design suggests that those sitting be placed in the center of the group with the people who stand placed around them. This would provide a little more elbow space for those standing, but each group can be expected to vary from this.

Although 5 square feet per person is allocated, space per se will not be identified except to instruct the first member of each newly forming group (as he enters the doorway of the building) to go to a particular area and, with the next 35 people entering the shelter, to reserve a space of about 12' x 15' for his group. He will automatically implement the space model. The model presented conforms to the crowding conditions and includes minimal extra space and pathway.

PLACEMENT MODEL FOR SHORT TERM PROTECTION



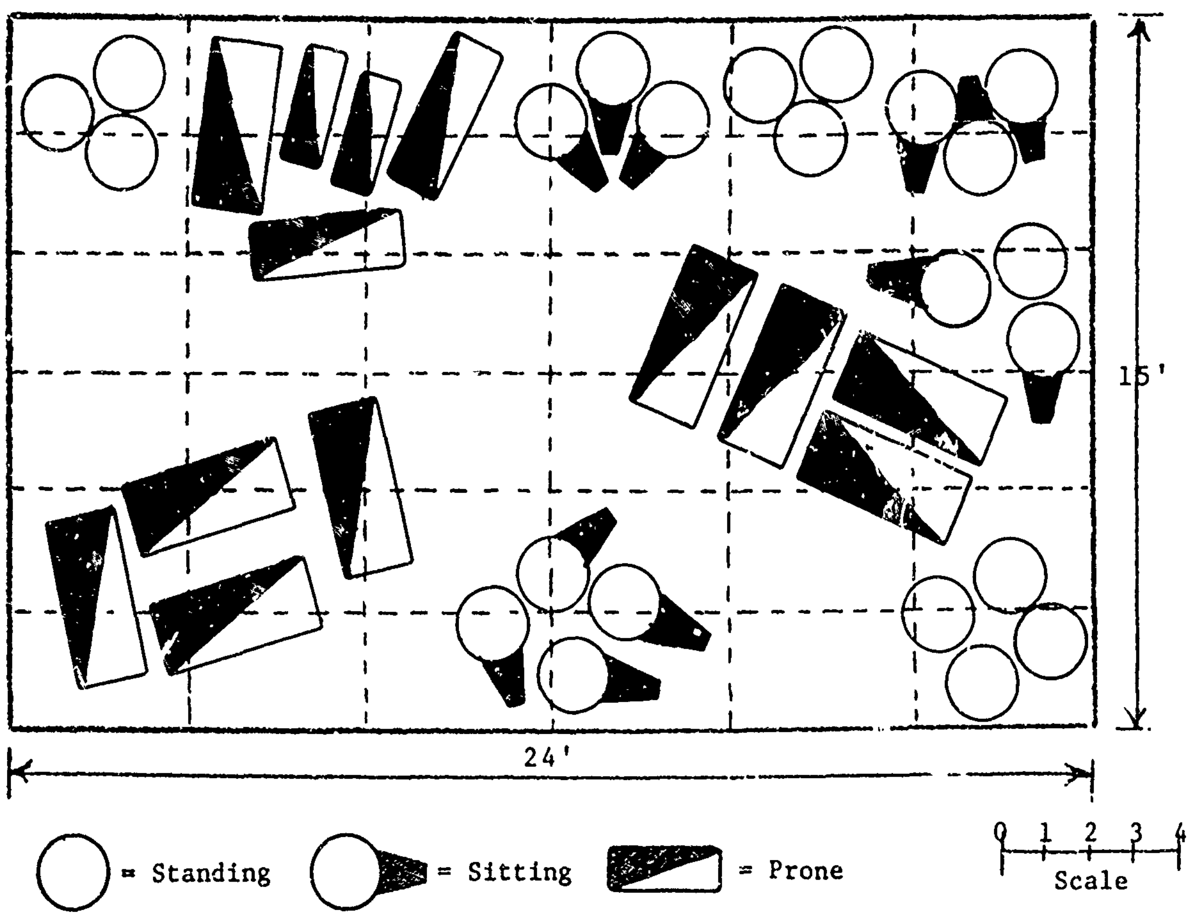
Squares enclosed by dotted lines = 2 x 2-1/2 feet = 5 square feet

Figure 21

Figure 22 shows the 10 square feet per person allocation currently being used to determine shelter space in buildings. In our study, this allocation of space figure is used for determining placement during the longer period of

confinement, i.e., when radioactive fallout is present one-half of the people will move out from the crowded areas into the fallout protection area, with those remaining taking up the space they vacated. Shelter management can move groups nearest the fallout protection area, but the choice should be left to them. They may wish to move certain groups who are creating problems of sorts or they may find they can take care of people with special needs better if they are placed in certain locations. The change in location should not result in a change in group membership. The group should move together into the new positions. Moving out of the crowded spaces of Figure 21 into the more comfortable positions in Figure 22 should be welcomed by the shelterees.

PLACEMENT MODEL FOR LONG TERM PROTECTION



Squares enclosed by dotted lines = 2-1/2 x 4 feet = 10 square feet

Figure 22

Application of Placement Model to Representative Buildings

The model for shelteree placement is here applied to the representative buildings: the school, the apartment, and the office building. Only physical space is considered since the section which deals with the problems associated with shelterees appears later.

The physical environment produced by nuclear and natural disasters is presented in Section II, pages 6-10, with the drawings appearing in the APPENDIX. A summary of the shelter capacity of the representative buildings is presented in Figure 23.

This discussion will apply to low, moderate, and high overpressure levels since it was found that in the representative buildings the area designated as blast protection area would offer some protection at all three levels.

The School. The best blast protection area in the school (7,500 sq. ft.) is unique in one sense, i.e., almost 2/3 of this blast protection area is the school auditorium. This section has 850 permanent seats plus wide aisles, a raised stage (some additional area beneath the stage), an auxiliary lighting system, and with its high ceiling and good system of ventilation can give adequate protection to more than 1,100 shelterees without any difficulty. Since under normal conditions more than 1,000 people can occupy this auditorium area for periods of several hours, the minimum overcrowding suggested in this study would not tax these facilities. The remainder of the school while not as adequately ventilated as the auditorium would none-the-less provide shelter for an additional 350-400 people. It is logical to assume that a high overpressure level would destroy part of the area designated as shelter (not crowded @ 10 sq. ft./person) against radioactive fallout. At the same time it could be assumed that portions of the building, not so designated, but on the side of the building away from the high over-pressure level burst would probably still be useful for protection against fallout. If all of the space beyond the blast protection area were destroyed or badly damaged it would be necessary to move some of the survivors to another shelter to reduce crowding.

The Apartment. The apartment building will provide shelter from bursts of low, medium, or high overpressure levels for approximately 1,500 people under conditions of crowding (5 sq. ft./person) which works out to five groups of 36 people each per floor. With all of the windows and doors sealed this would cause ventilation problems; however, if the windows were opened or

SHELTER CAPACITY FOR REPRESENTATIVE BUILDINGS

Best Areas for Protection

	School	Apartment	High-Rise Office
Best Fallout Shelter Space @ 10 sq. ft./person	2,750	2,500	16,200
Best Blast Shelter Space @ 10 sq. ft./person	750	750	7,400 + ventilation
Best Blast Shelter Space Sitting/Standing @ 5 sq. ft./person	1,500	1,500	7,400 + ventilation
Best Tornado Shelter Space @ 10 sq. ft./person	2,750	2,500	7,400 + ventilation
Best Flood & High Water Shelter Out of High Water Area 10'/person	5,300	4,500	100,000 +
Best Flood & High Water In High Water Area Shelter @ 10'/person	2,300	4,000	100,000 +

Figure 23

knocked out the problems associated with ventilation, heat, moisture, etc. would be resolved. On all floors the best blast protection area is the central core of the building with the two elevator shafts in the very center. If the elevator doors were removed or opened on each floor and the elevator skylights removed the elevator shafts would act like a chimney and provide superior ventilation for the entire blast protection area.

The apartment building, constructed of reinforced concrete with cast-in-place concrete interior walls and partitions, would probably suffer minimum structural damage from a low level blast so that in the post blast era sufficient fallout shelter space would be available to eliminate the crowded blast protection area.

The High-Rise Office Building. Some shelter against blast will be provided by the high-rise office building. And, it will do so rather comfortably (approximately 18 sq. ft./person) since the limiting factor with this model is not space but ventilation. All of this shelter area is below ground and the cost of providing more than a very small amount of additional ventilation would be prohibitive unless PVKs are used. Neither the model in Figure 21 nor Figure 22 would apply since at no time is crowding a factor.

If blast overpressures of medium or high intensity were to occur, the fallout shelter areas shown on floors 2 through 14 would not be usable since a blast of that intensity would probably take away the exterior curtain wall as well as all of the glass. If such a blast were to occur the floors above grade would not be usable and the shelter below grade could take no additional shelterees due to the lack of ventilation.

Shelteree and Shelter Management Concerns

This section examines the problems expected to be encountered in connection with the scheduling and placement of the shelterees. Basic problems, not specific to any particular disaster situation include: a) shelter capacity — grouping, positioning, crowding; b) supplies — water, food, medicine, and their distribution; and c) management to implement desired actions. The problems are differentiable by the type of disaster and thus where appropriate will be dealt with accordingly.

Shelter Capacity in a Nuclear Disaster

In the case of a nuclear disaster the maximum capacity of a shelter will be determined by the shelter's best blast protection area. The blast protection area is the area of a shelter which is sufficient to protect the shelterees from the blast's overpressures as well as the light flash and heat from the thermal pulse. The period of time that the shelterees are required to remain within the blast protection area is short, relative to the time they need protection from radioactive fallout, consequently during this period the shelterees may be forced into a situation which places them close to their mental and physical limitations.

The school building could accommodate a maximum of 2,500 people at approximately 3 square feet per person with standing room and with respiration needs fulfilled. If we assume that the shelterees may spend up to six hours in the blast protection area, a more reasonable maximum capacity would be 1,500. This lower figure serves two purposes: a) a shorter loading time and b) greater comfort.

The nine story apartment building could accommodate a maximum of 2,450 people at approximately 3 square feet per person. Following the same reasoning as with the school building, a more reasonable maximum capacity would be 1,500 people. It is important to note that loading time in this building would be significantly longer and consequently more critical than in the school building. This is true because the blast protection area in the school utilized only one floor while the corresponding area in the apartment building utilizes eight floors. The high-rise administration building (Building #3) could accommodate 7,400 shelterees at maximum allowing 18 square feet per person. Although this is physically a very uncrowded situation, additional people would overtax the natural and mechanical ventilation of this underground area.

To summarize, the primary problem in any physical structure in a nuclear disaster is that the blast protection area is smaller than the fallout protection area and thus the former becomes the shelter's capacity limiting factor. The maximum blast protection capacity has been calculater considering air supply, physical space, and load time.

Shelter Capacity in Natural Disasters

Floods. In a natural disaster, such as a flood, the shelter's maximum capacity assumes the entire building to be above the water level. Due to the sound structure of the buildings all of the exposed floors would provide safe refuge from the flood waters even if part of the building is submerged.

The maximum flood protection capacity of the school would be more than 53,000 square feet of protection. At approximately 10 square feet per person this would accommodate 5,000 + shelterees. These space allocations are made on the assumption that flood victims usually have no place to return to and must spend a longer period until their homes are restored or until more suitable housing is found for them.

The nine story apartment building could provide flood protection for 4,500 shelterees, if the entire building were above the water level. As each floor can hold about 800 people, this number would be the increment to

consider if less than all floors were suitable for protection.

The maximum sheltering capacity of the high-rise building, assuming no structural damage, would be over 100,000 shelterees.

Tornadoes. In another type of a natural disaster, a tornado with high winds, the capacity limiting factor depends upon protection from the pressures of the unusually strong winds. Excellent protection from high winds as well as the overpressures of the nuclear blast is found below ground; therefore, the basement and subbasement of the office building offer the best protection. The apartment's maximum wind protection, all above ground, would be 2,500 persons while the office building would accommodate approximately 7,400 shelterees — all below ground level. The school could provide safe shelter for approximately 2,750 persons

Supplies. Supplies are a major consideration, and their storage presents a dilemma of sorts. For a nuclear attack or wind protection the location of prime security is subterranian. However, for flood conditions, below ground storage is unsuitable. Without further research, to provide additional pertinent information it would be suggested that supplies may be stored in basements or subbasements, as during a flood supplies may be provided by helicopter whereas in a nuclear attack the transporting of supplies would probably not be possible. A tornado or hurricane situation is so short, having a duration of several hours, compared to several days or weeks for a nuclear attack or flood, that supplies would rarely become critical except for possibly medical supplies. Medical supplies should be available both above and below ground.

Management. Giving effective directions to and maintaining control of large groups of confused or frightened people can present quite a problem, although having most of the people already formed into subgroups should hold initial confusion to a minimum. The following seemingly workable solution is suggested for implementing directions and maintaining control.

Civil defense leadership for entire group is necessary and should be easily recognized by an obvious marking, (e.g., bright armbands or helmets — or, a piece of white paper attached with a paper clip). These leaders, via a battery operated public address system (e.g., megaphone) must be able to get the entire group's attention when desired. When the doors of the building are closed to await the impact of the disaster one of shelter management's (SM) first tasks will be to repeat the initial instructions for forming the

Sub-Groups (S-Gs) of 35 to 40 persons. If desired, a permanent S-G leader (S-GL) may replace the initial group leader who just happened to be the first person in a unit of 36 people and was assigned the responsibility for forming the group. Each S-G must have a leader and each S-GL must be distinguishable (by a number, etc.).

The S-GL will work directly with Major Group Leaders (MGL) (one MGL for every 12 S-GLs) who are in turn responsible to SM, i.e., the shelter manager or management for the entire building. Medical and Supply (M&S) divisions will have their own leaders who work between the SM and its divisions. The divisions will work with the S-G through the MGL. With S-Gs organized as such, S-GLs could organize and locate the S-Gs as specified by the MGLs.

The goal of this type of organization is, while keeping everything simple, and straight forward, to maintain control and to have directives given and followed — and to do this swiftly, accurately, and with minimum confusion.

Behavioral Objectives

Simplicity is the key to the solutions presented. All elements contained in the solutions to the problem are in simple, familiar terms to facilitate understanding and memory by the shelterees, group leaders, and sub-group leaders. And, if a policy for temporararily overcrowding a shelter were to become implemented on a national scale, basically only one question would have to be answered: can the ventilation for the particular shelter handle twice as many people for several hours? The number of hours a shelter can handle an overload of people is a critical factor and should be permanently recorded.

The problem and solutions to the problem are restated here for the convenience of the reader. The problem set up for study is to determine actions to take for maximizing the lifesaving potential of buildings and then to determine how to implement the actions.

The solution recommended is to load shelters to twice their normal (10 sq. ft./person) occupancy capacity in the impact period of a nuclear detonation or during selected natural disasters. The shelter population is to form groups of 36 as it enters the building and proceeds to the blast protection area. There, each group is to fill an area of about 12 x 15 feet (or an average of 5 sq. ft./person). Twenty-four people (2/3) are to stand and 12 (1/3) are to sit on the floor. Each shelteree alternates ten

of sitting with twenty minutes of standing. Each group is to have a leader, designated by someone from shelter management, as it enters the building (the first person of approximately every 36 people).

The behavioral objective discuss the basis for the solution noting the advantages and disadvantages inherent or planned for and the behavioral problems solved by the solution or remaining to be solved.

A combination of sitting and standing postures was selected in preference to having everyone standing continuously. This combination of postures requires more room (5 sq. ft./person vs. 3 sq. ft./person if everyone stands) but is necessary because a slight cushion of space and pathway areas are needed. Also, this amount of space is needed for everyone to lie down during the period awaiting attack.

A cushion of extra space is required to allow for long term lying-down room. If someone becomes ill or faint, some space should be immediately available for that person. To resolve this, one or two people who are seated can give up that space. Some people may prefer to remain standing providing some extra space — thus, special needs to sit or lie down can be met.

Part of the cushion of space should be used for storage of personal belongings which will appear in spite of instructions to bring items limited to necessity. Blankets can be used to sit upon but most other items simply will be in the way. With shelterees likely unwilling to part with personal belongings, it would prove psychologically wise to simply provide some dual purpose space for them.

The sitting/standing procedure provides realistically for those who are unable to stand for long periods of time. These include older and younger people as well as those with minor physical or emotional problems. Not every person is going to be able to stand and arrangements should be made at the beginning for some to sit for longer periods of time.

The combination of sitting and standing gives the illusion of more space than actually exists. It also allows for greater shelter visibility. This is important for the shelterees but more so for shelter management, The latter can view the entire group and quickly respond to problems as they develop.

Visibility within the shelter is important to family structure. Families should be kept together (even if the group size exceeds 36 slightly to do so) and if they become separated, they can find each other more readily.

Taking inventory is important to an individual in disaster. People will want to know who is where. The fact that they can look over the group — will

be comforting — though it is not a lifesaving behavior. People want to be assured of their actions and this assurance often is brought about by the fact that others acted in the same way.

An unexpected advantage of being in a crowded position is the feeling of space that will evolve when the shelterees move into areas twice the size they are in.

Additionally comforting will be the shelteree's understanding of what is going on — the rules for establishing their group and the scheduling of postures are easily understood.

Imposed actions create a dependency — that is, the shelterees have depended thus far upon someone else to tell them what to do. Those who are predominately independent will strive to contribute their knowledge and skill and will try to participate as soon as possible. Identity with a small group will give them a modus operendi; they can be counted upon to assist shelter management in carrying out the needed actions.

Crowding is a phenomenon which is primarily psychological in nature although an excess of people usually is involved. The chance for crowding problems is possible with the solutions set up; however, the measures discussed have been developed to minimize this possibility.

The foregoing summarizes some of the advantages or positive aspects as well as limitations one might anticipate in implementing the procedures set up in the study. The procedures are not peculiar to overloading shelters but would apply also to the normal loading of a shelter with fewer people.

IV. SUMMARY

The purpose of the study is to identify and define the problems met in getting shelterees to take action for maximum protection against the full effects of a nuclear detonation or a natural disaster.

Three knowledge areas serve as a resource in the resolution of the problem set up for study. These areas are presented as the physical, the biological, and the psychological environments.

The physical environment in the study is a hostile one which could emerge during either a nuclear attack with high, medium, or low intensity blast effects or a natural disaster exemplified by a tornado or a flood. Three models are used as examples to demonstrate induced protective behavior from the hostile physical environments. These models include: a modern school building, a nine-story apartment building, and a high-rise office building. They were selected as being representative of buildings found in urban settings. The models include a variety of building construction to illustrate a variety of behavioral problems.

The biological environment is viewed in terms of the damage potential of the hostile physical environments. Basic life preserving action is necessary to prevent biological damage. Important damaging effects arise in a nuclear disaster from the blast and shock, the thermal radiation, and the nuclear radiation. In a natural disaster the biological damage arises from excessive water or winds, or their secondary effects. The kind and extent of biological damage depends upon the nature of the protection available.

The psychological environment is the milieu in which behavior takes place. In it people respond as individuals and as members of groups as they attempt to deal with the conditions imposed by disasters. Disaster produces stress and this pervades behavior. Basic responses are made in terms of the time stage of the disaster with each individual following a predominant style of behavior. The individual is seen as having unique needs, resources, and experiences which occur as dimensions of his personality. A shelter population is seen to be made up of newly formed groups of such individuals. These interact within a newly formed structure to meet lifesaving goals which they hold in common with society as communicated through its civil defense.

Knowledge relating to the three environments has been summarized and used as the basis for setting up the problem and for its resolution. Identified in each problem resolution are the components of actions to be taken for maximum protection and steps necessary to communicate the directives to the people to obtain the necessary lifesaving actions.

Central to the resolution recommended is the provision for shelterees' psychological needs along with the necessary physical protection. The analysis found that total needs could best be met by allocating five square feet per person for short term occupancy in the best blast protection area, doubling the officially estimated shelter capacity. Groups of thirty-six people are to work together as a unit with, at any given time, one-third sitting on the floor and two-thirds standing, during periods of ten and twenty minutes, respectively. All take prone positions during the very short period when an attack is imminent and the direct effects of a blast are possible. At other times the sitting/standing sequence applies. The model is designed to cover a period of up to six hours duration, before an attack is imminent. Following an attack, people would spread out into other areas for the longer period of confinement required for protection from fallout.

Behavioral problems are less likely to arise if the procedures set up for implementing the overloading conditions are used. The temporary postures recommended permit some flexibility to meet the needs of individuals and groups as they arise.

One building was not amenable to these conditions and served to demonstrate that the overcrowding capability of a building depends upon the characteristics of its physical environment, primarily its ventilation capability.

V. CONCLUSIONS AND RECOMMENDATIONS

Three buildings were selected to serve as examples to portray problems which might be met if maximum use were made of the best areas of protection in shelters. The best area is that which will offer the greatest protection against the effects of blast and thermal pulse.

Using the three buildings, it was found that the limiting factor for a building's occupancy capacity was the availability of areas with sufficient shielding to protect the people from the overpressures of blast. With a burst of any size likely, only maximum blast protection areas could be used for overloading for short term protection during the burst's impact phase.

Whether or not a shelter can be overloaded is dependent upon characteristics of the physical environment. In fact, the predominant variable which will determine a shelter's suitability for overloading is its ventilation capability. Ventilation and cooling needs remain important concerns. If a shelter can provide a life preserving biological environment for the shelterees, the plan for overloading shelters to 200% capacity (5 sq. ft./person vs. 10 sq. ft./person) is realistic.

Five square feet per person were found to be a reasonable allocation of space. The placement procedures worked out for the temporary postures appear feasible. Placement procedures were developed for both short and long periods of confinement. Groups of thirty-six people are to work together as a unit. At any given time, approximately one-third of a group are to sit and two-thirds are to stand, during periods of ten and twenty minutes, respectively. The procedures set up to implement the scheduling and placement were kept simple and appear to be easily understood and remembered. The behavioral problems to be encountered can be minimized if the procedures set up are used.

Recommendations are offered in three problem areas: loading time, shelter management, and ventilation. It can be expected to take longer to load a shelter if it is to contain twice as many people as normal. This does not necessarily mean that it will take twice as long to load. It may take only a few minutes longer or much longer. Empirical data on this question would be useful and not difficult to obtain.

General guidelines for implementing the overloading procedures are included. It would be profitable to expand these, putting greater emphasis upon utilizing the resources of the shelterees. Continued work in this area is recommended.

The model, as presented, should be tested in several existing shelter environments. Computer simulation could provide valuable data, especially in the area of ventilation and other environmental effects. In addition, it would be helpful to learn if there might be an optimum size for overloading — thus, 1,500 might prove an unwieldy number whereas smaller groups might be able to temporarily overload the capacity of buildings.

In summary, many of the behavioral problems have been provided for. Several problems relating to the physical environment continue to require study.

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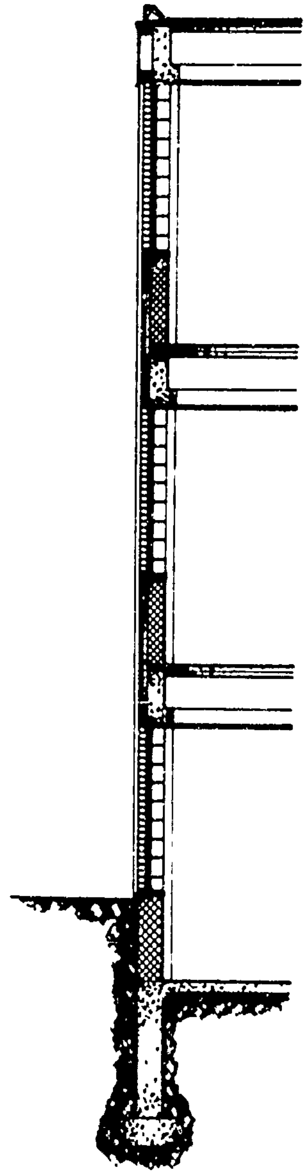
APPENDIX

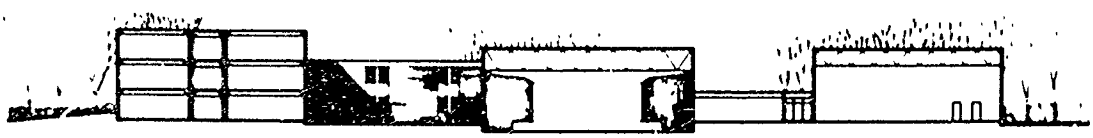
BUILDING 1 - SCHOOL

CONSTRUCTION DATA

STRUCTURAL FRAME	Reinforced concrete
FLOOR	Precast concrete T's (12-inch forms + 2-1/2 inches concrete w/4-inch joists @ 24-inch c/c; wt = 63 psf) 2-1/2-inch concrete topping Acoustical tile ceiling Dead load = 90 lbs./sq. ft.
EXTERIOR WALLS	4-inch face brick or stone 1-inch rigid insulation 8-inch concrete block Dead load = 90 lbs./sq. ft.
INTERIOR PARTITIONS	6-inch concrete block Dead load = 90 lbs./sq. ft. (solid block)
ROOF	Precast concrete T's Lightweight concrete topping Built-up tar & gravel roofing Acoustical tile ceiling Dead load = 66 lbs./sq. ft.
GRADE	Grade at sill height (3 ft.) on south & west walls
GLASS	1/4-inch heat-absorbing plate

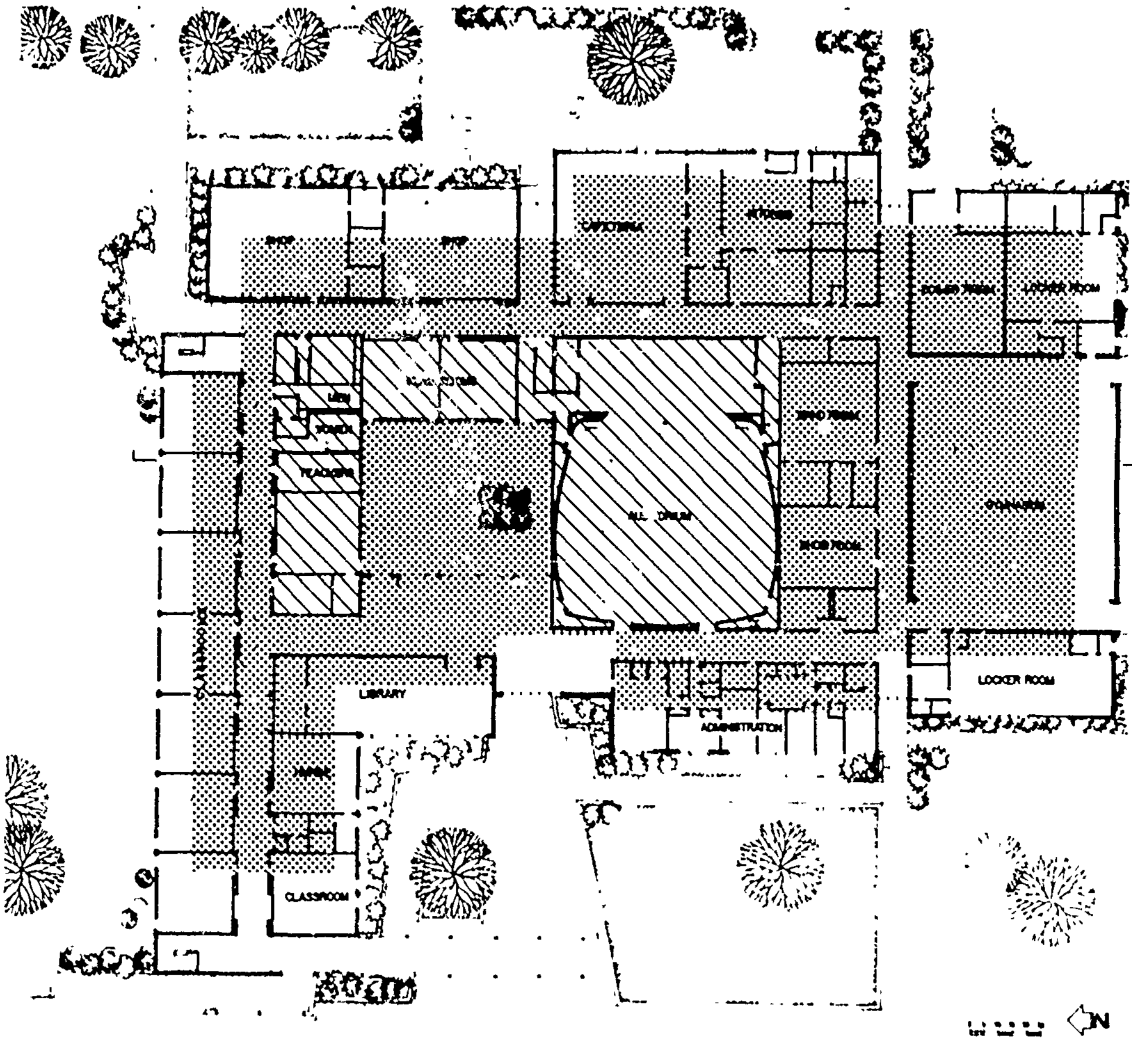


TYPICAL WALL DETAIL
NO SCALE



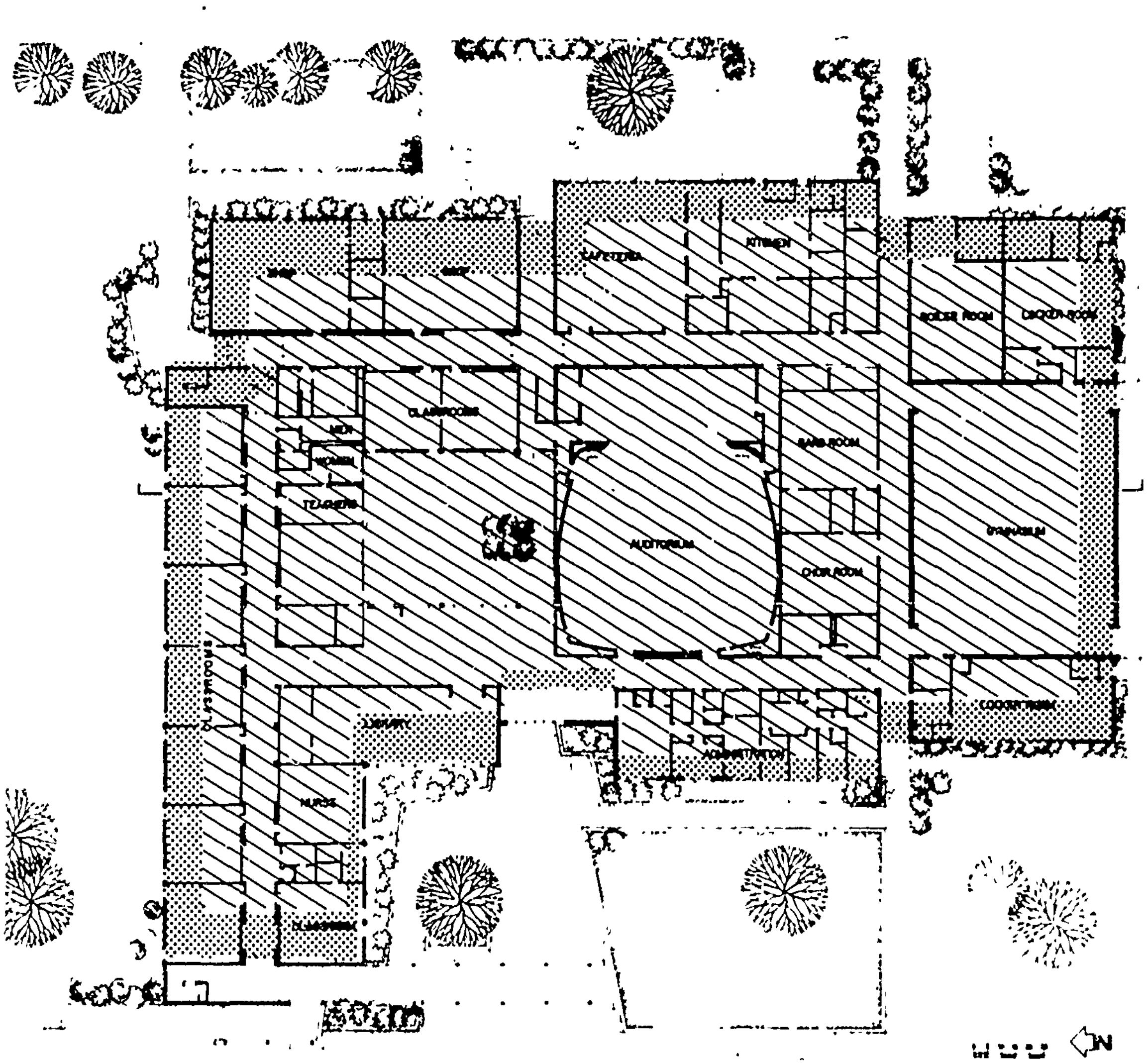
SECTION A-A
NO SCALE

DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
CONSTRUCTION DATA	DRI May 1972
BUILDING NUMBER 1	FIGURE 1



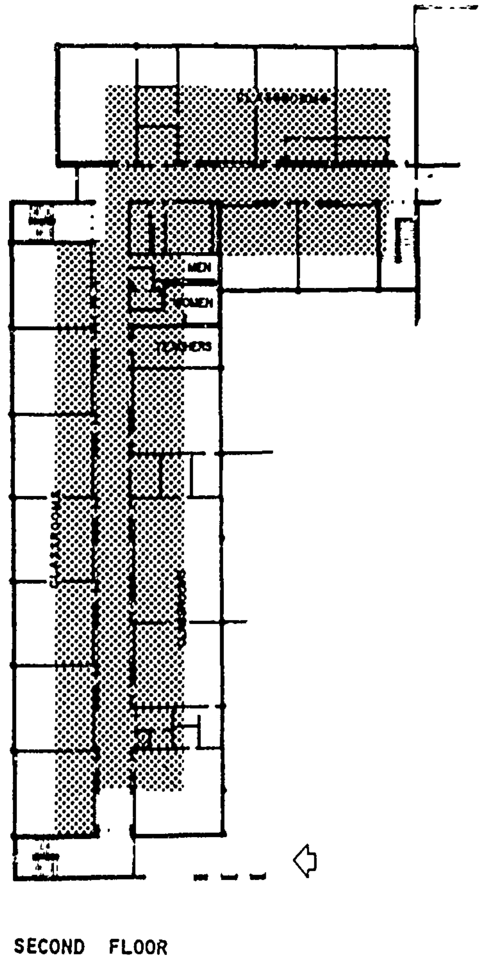
FALLOUT PROTECTION	
BLAST PROTECTION	

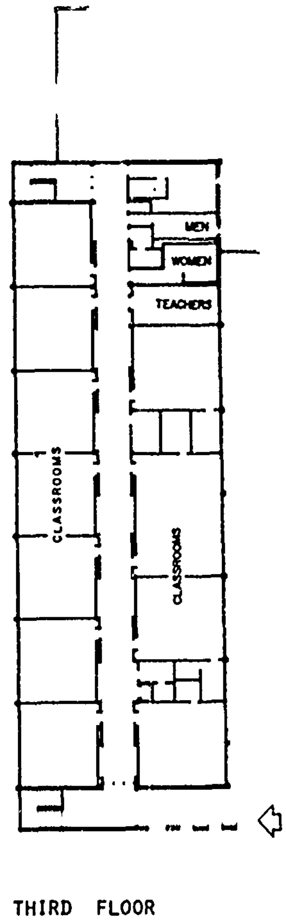
DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
FLOOR PLAN — FIRST FLOOR FALLOUT AND BLAST PROTECTION	DRI May 1972
BUILDING NUMBER 1	FIGURE 2



FLOOD PROTECTION	
TORNADO PROTECTION	

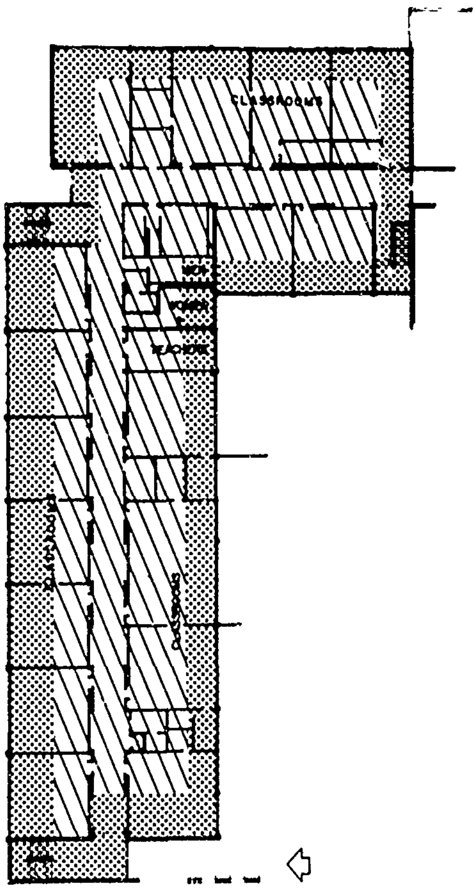
DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
FLOOR PLAN — FIRST FLOOR FLOOD AND TORNADO PROTECTION	DRI May 1972
BUILDING NUMBER 1	FIGURE 3



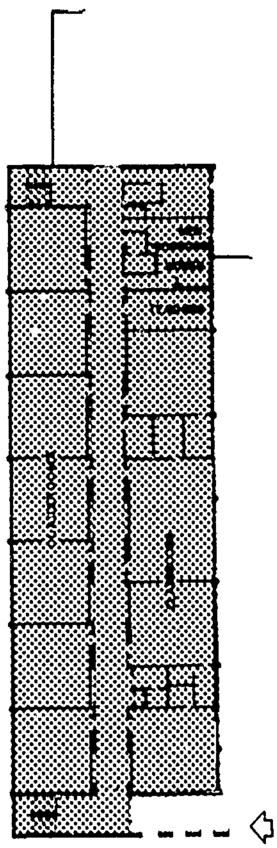


FALLOUT PROTECTION	

DEVELOPMENTAL RESEARCH, INC. P.O. Box 671, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
FLOOR PLANS -- SECOND & THIRD FLOORS FALLOUT PROTECTION	DRI May 1972
BUILDING NUMBER 1	FIGURE 4



SECOND FLOOR



THIRD FLOOR

FLOOD PROTECTION	
TORNADO PROTECTION	

DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
FLOOR PLAN — SECOND & THIRD FLOORS FLOOD AND TORNADO PROTECTION	DRI May 1972
BUILDING NUMBER 1	FIGURE 5

BUILDING 2 - APARTMENT

CONSTRUCTION DATA

NUMBER OF STORIES	Nine	
AREA PER STORY	5,940 square feet	
TYPE OF CONSTRUCTION	Reinforced concrete frame	
EXTERIOR WALLS	Story	
	1	Concrete block, non-reinforced
	2-9	Precast concrete and concrete block
INTERIOR PARTITIONS	Story	
	1-9	Concrete, cast-in-place
	-	Concrete block, non-reinforced
FLOORS	Story	
	2-9	Concrete beams, cast-in-place
	-	Concrete, one-way ribbed joists
ROOF	Story	
	-	Concrete beams, cast-in-place
	-	Concrete, one-way ribbed joists

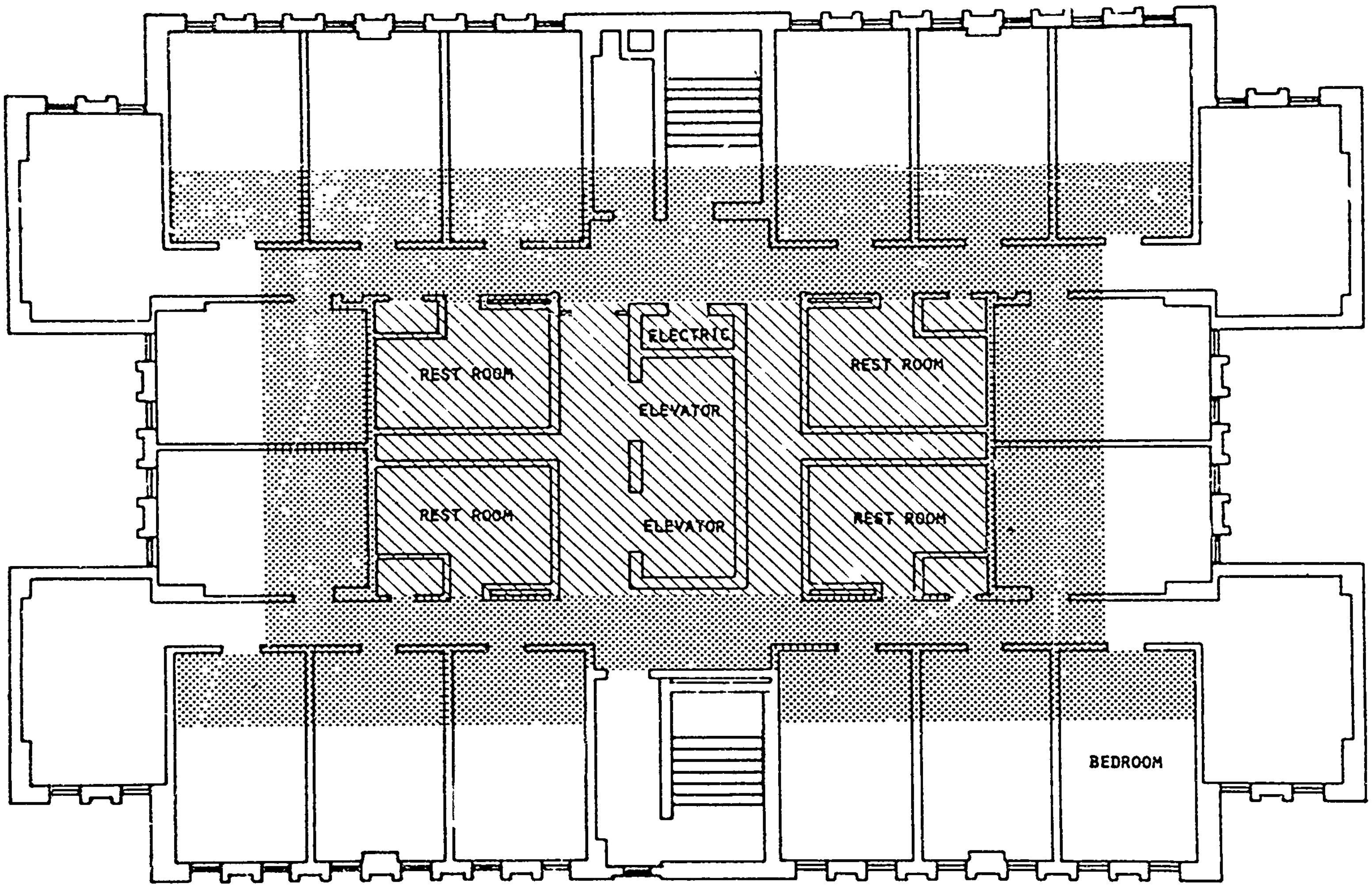
SLANTING TECHNIQUES

1. Raised the sill heights of windows on Sides A and C to 3 feet on the first story.
2. Filled the partitions surrounding the shelter area on the first story with sand.
3. Added two screening walls on the first story.

SHELTER SPACES

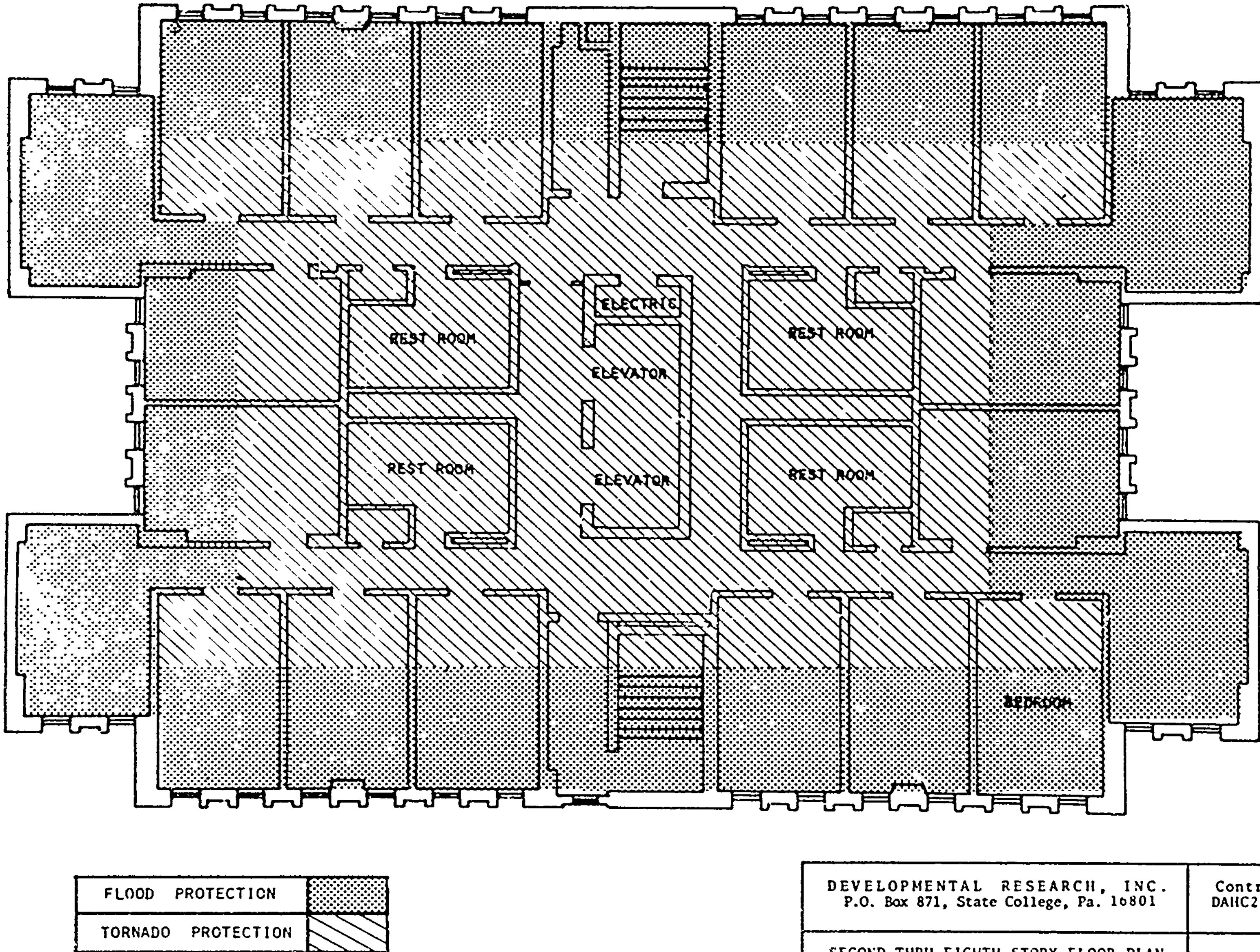
Story	Inherent	Added	Total
1	0	95	95
2-9	2,418	0	2,418
Total	2,418	95	2,513

DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
CONSTRUCTION DATA	DRI May 1972
BUILDING NUMBER 2	FIGURE 6

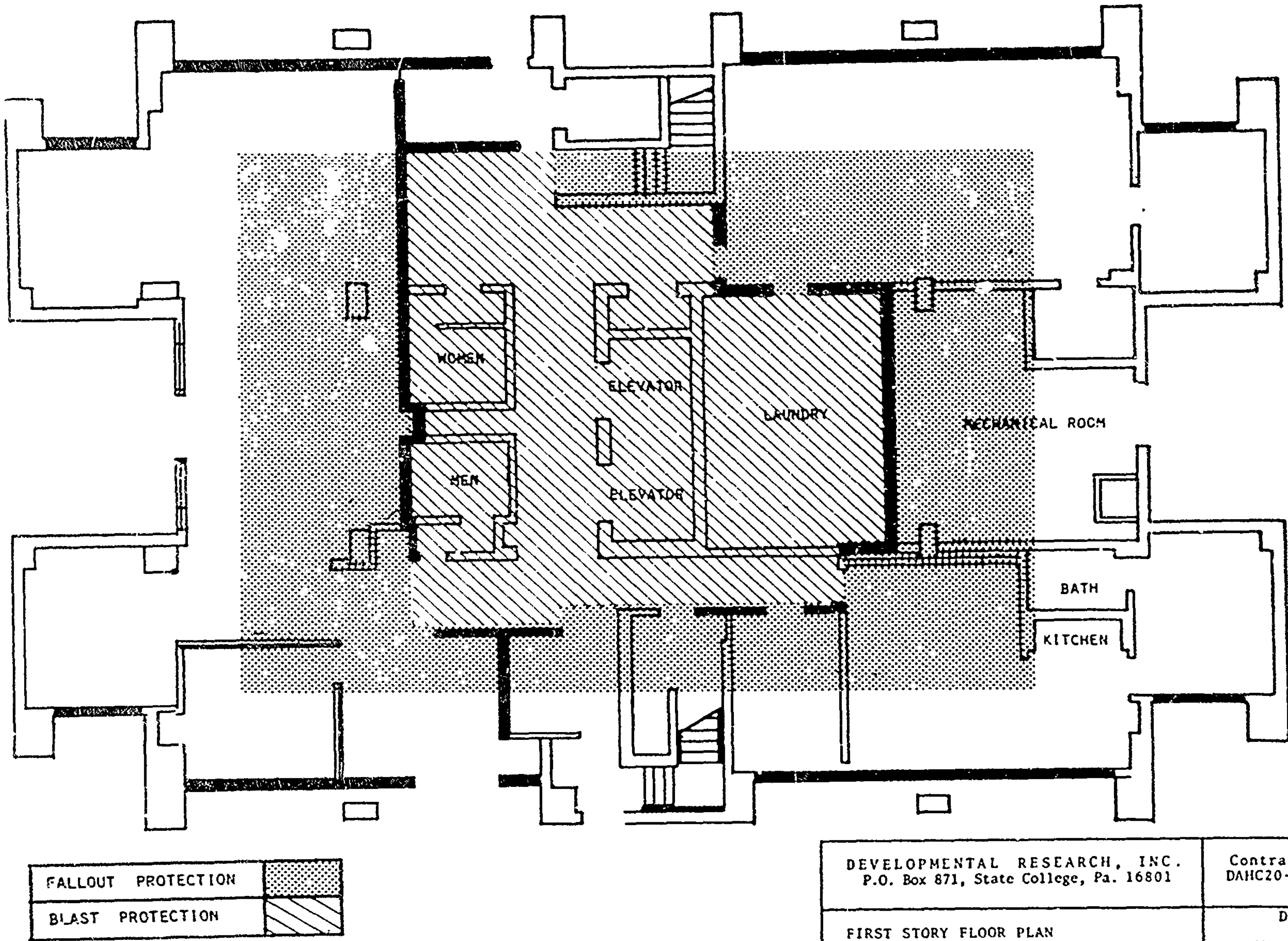


FALLOUT PROTECTION	
BLAST PROTECTION	

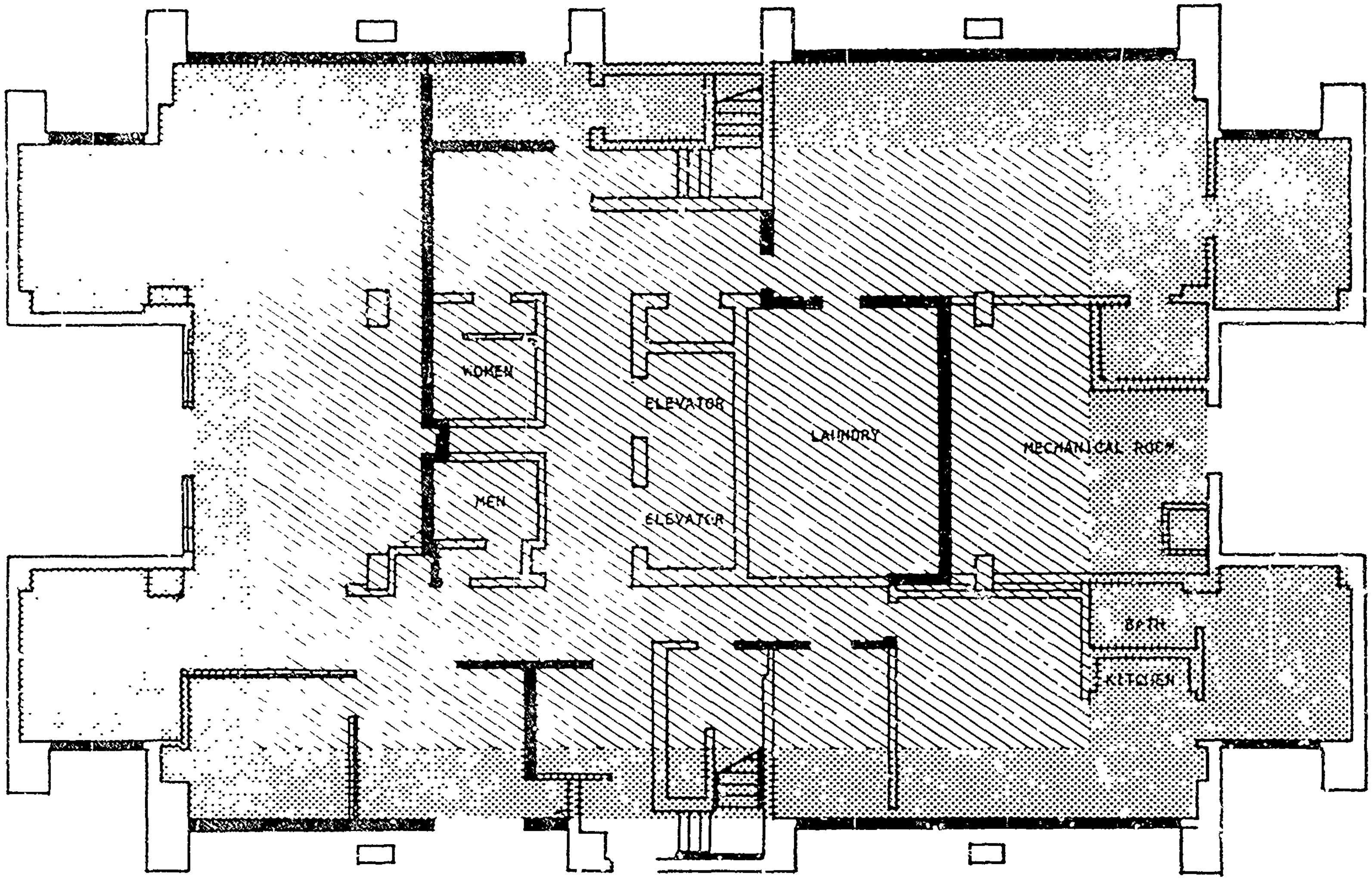
DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
SECOND THRU EIGHTH STORY FLOOR PLAN FALLOUT AND BLAST PROTECTION	DRI May 1972
FALLOUT AND BLAST PROTECTION	FIGURE 7



DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
SECOND THRU EIGHTH STORY FLOOR PLAN FLOOD AND TORNADO PROTECTION	D_{R_I} May 1972
BUILDING NUMBER 2	FIGURE 8



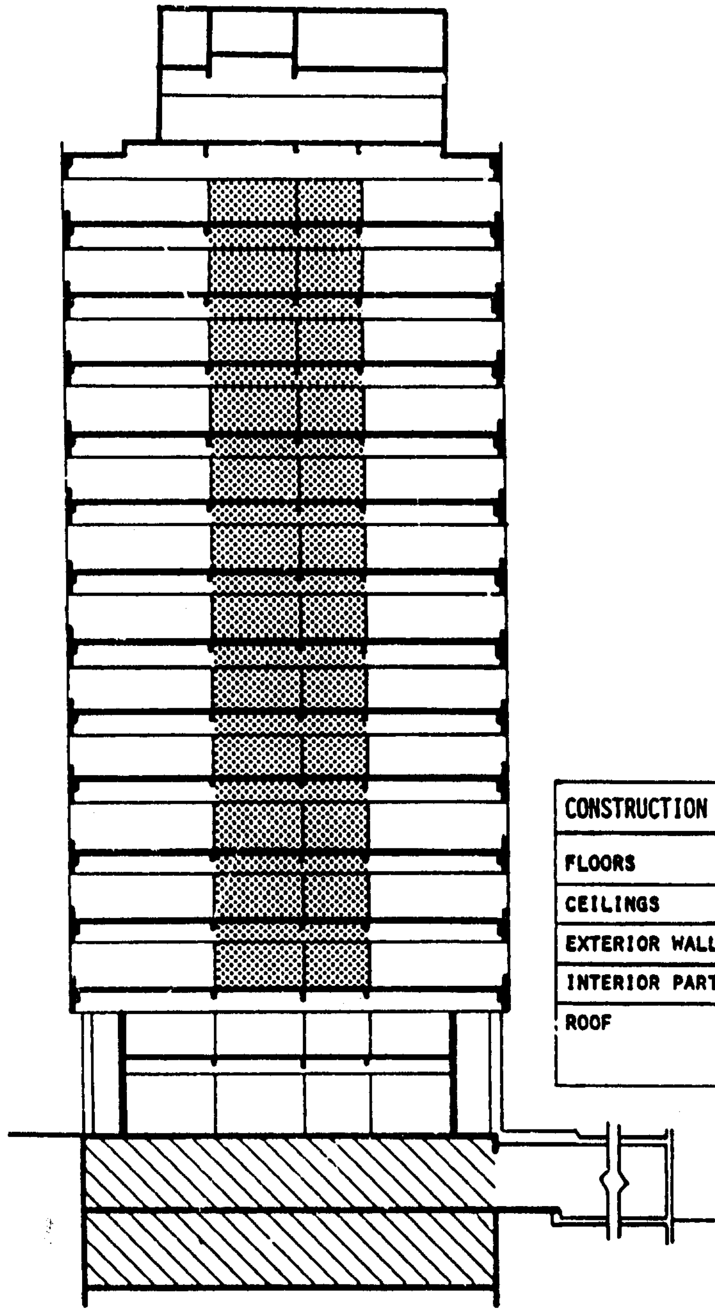
DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
FIRST STORY FLOOR PLAN FALLOUT AND BLAST PROTECTION	D_{R_I} May 1972
BUILDING :BER 2	FIGURE 9



FLOOD PROTECTION	
TORNADO PROTECTION	

DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
FIRST STORY FLOOR PLAN FLOOD AND TORNADO PROTECTION	DRI May 1972
BUILDING NUMBER 2	FIGURE 10

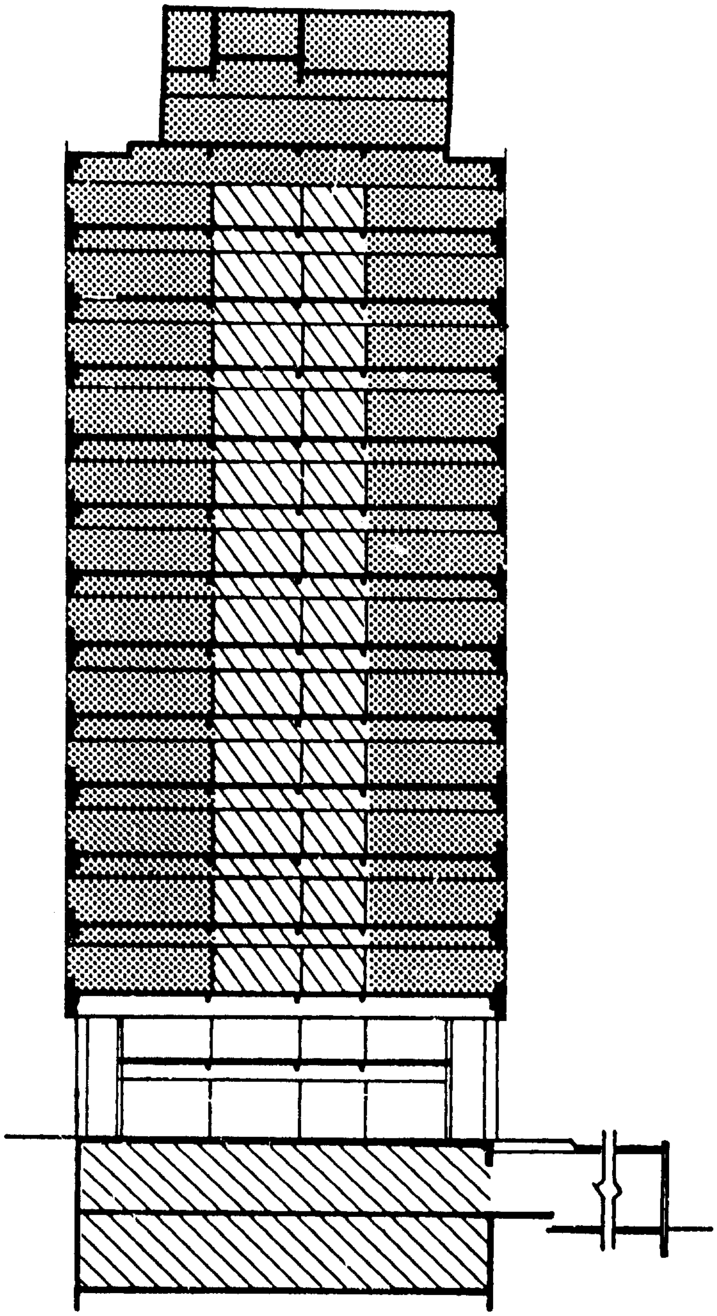
BUILDING 3 - ADMINISTRATION BUILDING



CONSTRUCTION DATA	
FLOORS	POURED CONCRETE PAN
CEILINGS	ACOUSTICAL TILE
EXTERIOR WALLS	PRECAST CONCRETE
INTERIOR PARTITIONS	MOVEABLE METAL
ROOF	POURED CONCRETE BUILT-UP T & G ACOUSTICAL TILE

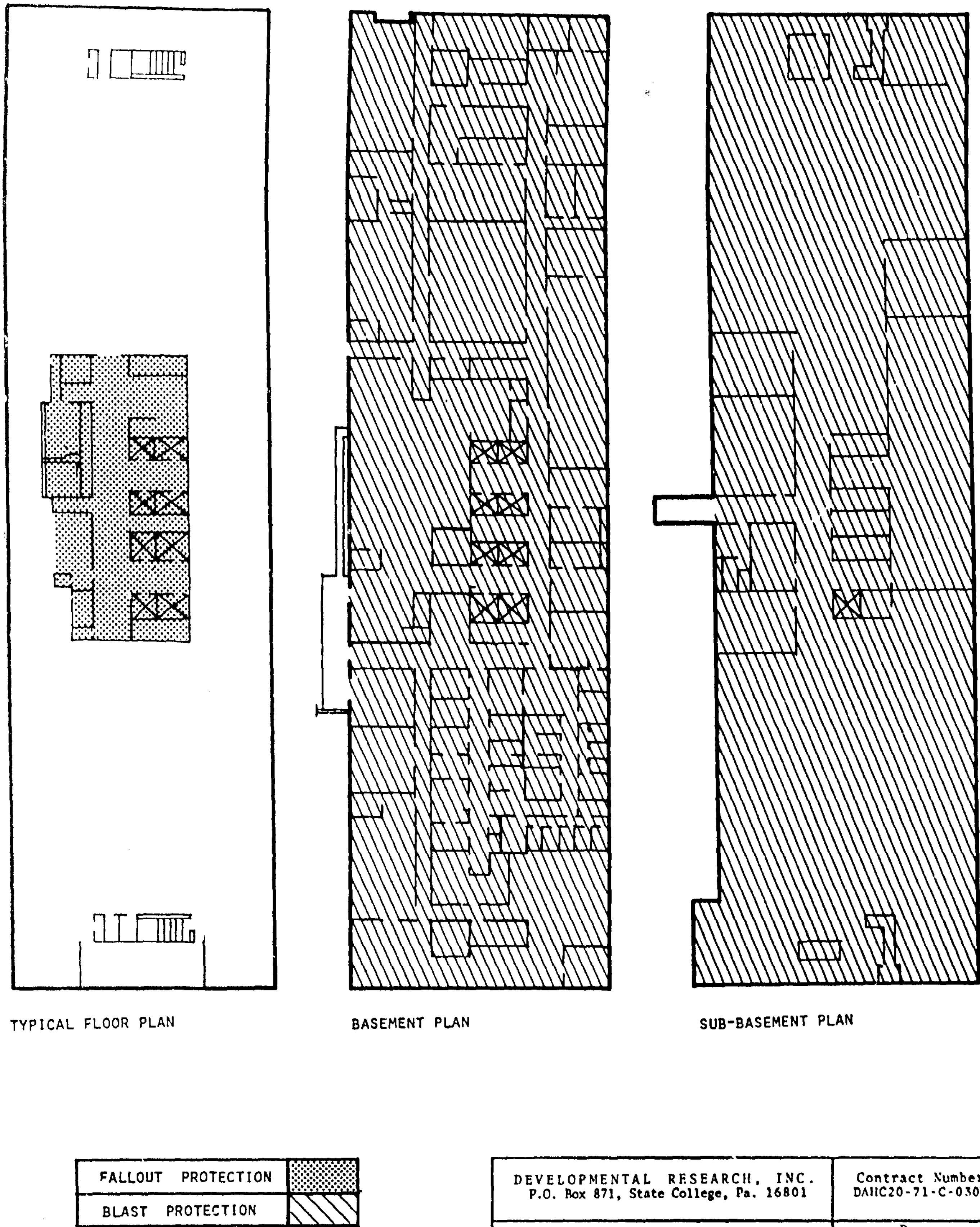
FALLOUT PROTECTION	(stippled)
BLAST PROTECTION	(hatched)

DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
ELEVATION; CONSTRUCTION DETAILS FALLOUT AND BLAST PROTECTION	DRI May 1972
BUILDING NUMBER 3	FIGURE 11

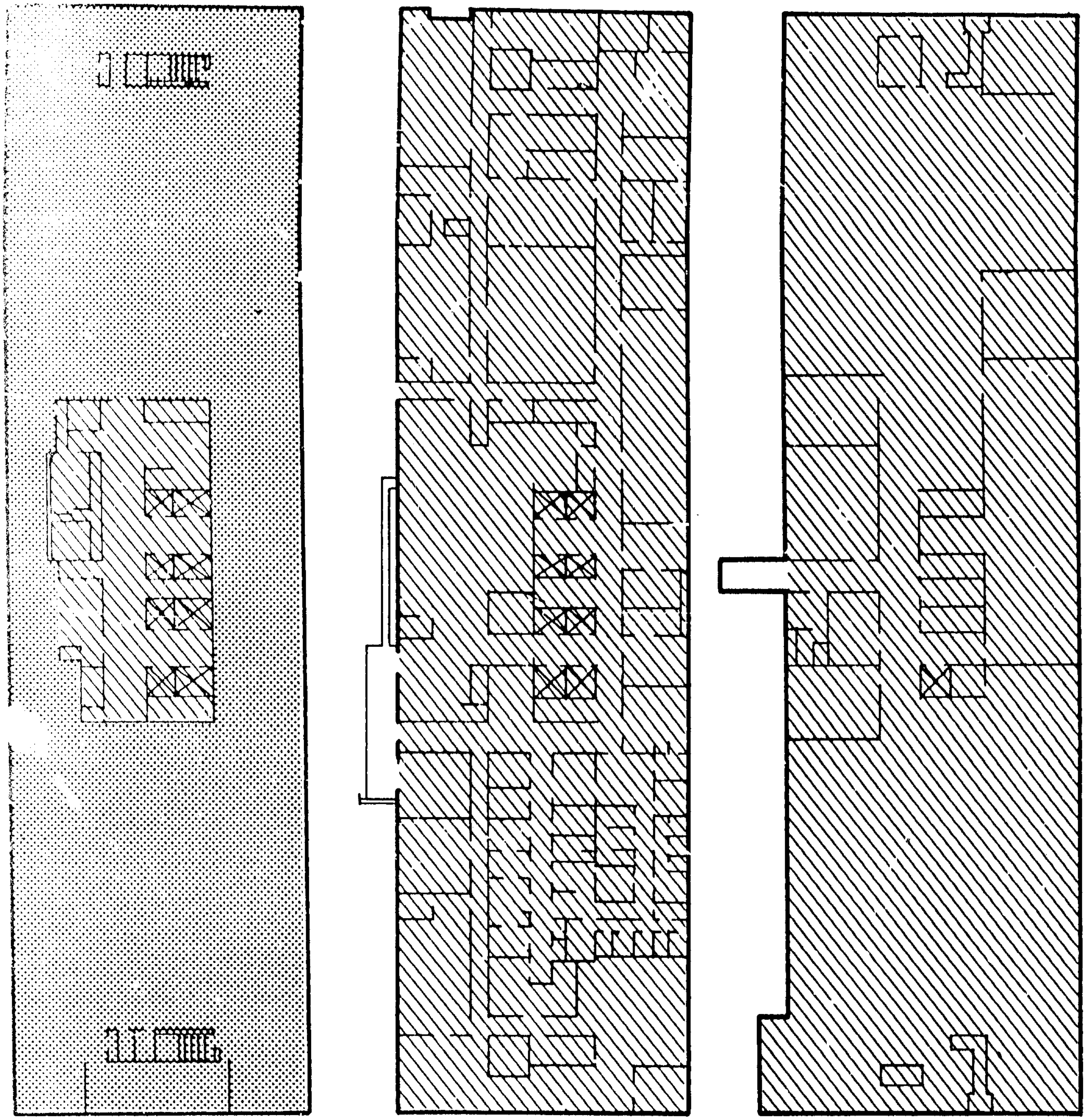


FLOOD PROTECTION	
TORNADO PROTECTION	

DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
ELEVATION; CONSTRUCTION DETAILS FLOOD AND TORNADO PROTECTION	DRI May 1972
BUILDING NUMBER 3	FIGURE 12



DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
FLOOR PLANS FALLOUT AND BLAST PROTECTION	DRI May 1972
BUILDING NUMBER 3	FIGURE 13



TYPICAL FLOOR PLAN

BASEMENT PLAN

SUB-BASEMENT PLAN

FLOOD PROTECTION	
TORNADO PROTECTION	

DEVELOPMENTAL RESEARCH, INC. P.O. Box 871, State College, Pa. 16801	Contract Number DAHC20-71-C-0306
FLOOR PLANS FLOOD AND TORNADO PROTECTION	DRI May 1972
BUILDING NUMBER 3	FIGURE 14